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Environmental Pathway Models for Estimating Population Health Effects from Disposal of High-Level Radioactive Waste in Geologic Repositories

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This technical report presents the methodology used to assess the long-term population risks from projected releases of waste from a geologic repository. It describes the models that the Agency developed specifically expects that population distributions, food chains, and living habits may change dramatically over 10,000 years. Rather than attempt to predict such changes, this methodology uses very general models of environmental pathways that consider present values for the various parameters used in the modols.

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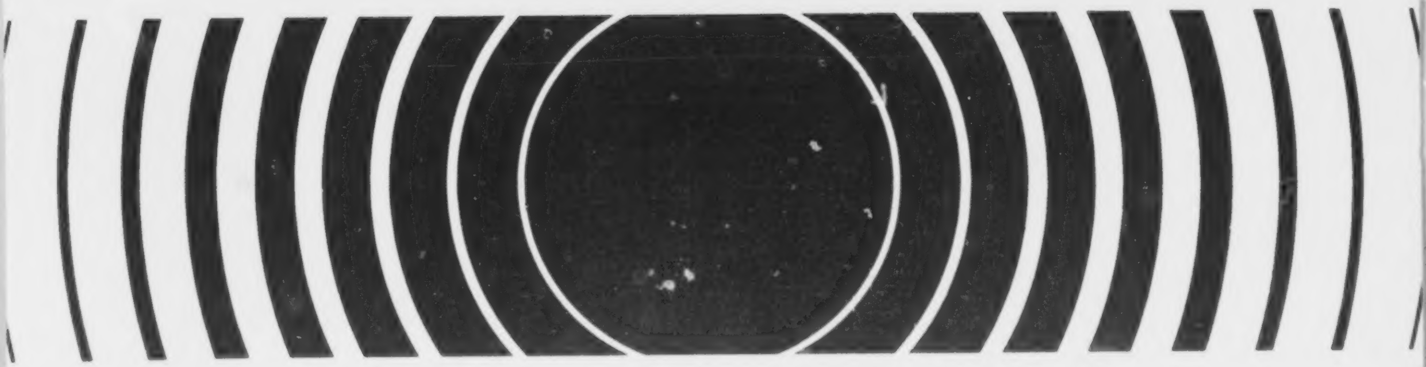

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ENVIRONMENTAL PATHWAY MODELS FOR ESTIMATING POPULATION HEALTH EFFECTS FROM DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTE IN GEOLOGIC REPOSITORIES

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December 1982

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FOREWORD

The Agency has recently published environmental standards addressing disposal of high-level radioactive wastes (40 CFR Part 191) for public review and comment (47 FR 58196). An important part of this effort is the evaluation of how effective mined geologic repositories are for isolating these wastes from the environment for many thousands of years. EPA's assessments indicate that carefully designed repositories at good sites can keep long-term risks below those that would exist if (on a generic basis) the uranium ore used to create the wastes had not been mined to begin with. Accordingly, the Agency has proposed environmental standards that would restrict projected releases from high-level waste disposal systems--for 10,000 years after disposal--to levels that should keep the risks to future generations less than the risks they would have been exposed to from the unmined ore if these wastes had not been created.

This technical report presents the methodology used to assess the long-term population risks from projected releases of waste from a geologic repository. It describes the models that the Agency developed specifically for this project and reviews the various assumptions made. The Agency expects that population distributions, food chains, and living habits may change dramatically over 10,000 years. Rather than attempt to predict such changes, this methodology uses very general models of environmental pathways that consider present values for the various parameters used in the models.

Because much of this methodology is new, and because these risk assessments are a key part of our rulemaking, the Agency is publishing this as a draft report. During the public comment period on 40 CFR 191, a Subcommittee of the Agency's Science Advisory Board will conduct an independent technical review of our risk assessments (48 FR 509). All meetings of this Subcommittee will be announced in the Federal Register and will be open to the public.

In addition, I encourage users of this report to submit any comments or suggestions they might have. Such comments would be most helpful if received by May 2, 1983, and they should be sent to: Central Docket Section (A-130); Environmental Protection Agency; Attn: Docket No. R-82-3; Washington, D.C. 20460. For additional information, please contact Mike Smith at (205) 272-3403; Office of Radiation Programs; Eastern Environmental Radiation Facility; Environmental Protection Agency; P.O. Box 3009; Montgomery, Alabama 36193.

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TABLE OF CONTENTS

Page

SUMMARY 1

S.1 The Methodology 2

S.1.1 Releases to a River (Surface Water) 3
S.1.2 Releases to an Ocean 5
S.1.3 Releases Directly to Land Surface 6
S.1.4 Releases Due to a Volcanic Eruption or Meteorite Impact 7

S.2 Results 7

1. INTRODUCTION 10

1.1 Background Information 10
1.2 Pathways Considered 12
1.3 Approach to Calculations 14

2. SOURCE TERMS 15

2.1 River Source Terms 15
2.2 Ocean Source Terms 20
2.3 Land Surface Source Terms 20
2.4 Volcano/Meteorite Interaction Source Terms 21

3. ENVIRONMENTAL TRANSPORT AND DOSIMETRY MODELS 22

3.1 Releases to a River 24

3.1.1 General Considerations 24
3.1.2 Drinking Water Ingestion 24
3.1.3 Fresh Water Fish Ingestion 26
3.1.4 Food Ingestion 27
3.1.5 Inhalation of Resuspended Material 30
3.1.6 External Dose - Ground Contamination 34
3.1.7 External Dose - Air Submersion 35

3.2 Releases to an Ocean 36

3.2.1 General Considerations 36
3.2.2 Two - Compartment Ocean Model 39
3.2.3 Seafood Ingestion 41

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TABLE OF CONTENTS (continued)

Page

3.3 Releases to Land Surface 42

  3.3.1 General Considerations 42
  3.3.2 Food Ingestion 43
  3.3.3 Inhalation of Resuspended Material 46
  3.3.4 External Dose - Ground Contamination 49
  3.3.5 External Dose - Air Submersion 49

3.4 Releases Due to Volcano/Meteorite Interaction 50

  3.4.1 General Considerations 50
  3.4.2 Releases Directly to Land Surface 51

    3.4.2.1 General Considerations 51
    3.4.2.2 Food Ingestion 51
    3.4.2.3 Inhalation of Resuspended Material 52
    3.4.2.4 External Dose - Ground Contamination . . . 52
    3.4.2.5 External Dose - Air Submersion 52

  3.4.3 Releases to Air Over Land 52

    3.4.3.1 General Considerations 52
    3.4.3.2 Air-Above-Land Two Compartment Model . . . 53
    3.4.3.3 Food Ingestion 56
    3.4.3.4 Inhalation of Dispersed and Resuspended Material 59
    3.4.3.5 External Dose - Ground Contamination . . . 59
    3.4.3.6 External Dose - Air Submersion 60

  3.4.4 Releases to Air Over Ocean 60

    3.4.4.1 General Considerations 60
    3.4.4.2 Air-Above-Water Three Compartment Model . . 61
    3.4.4.3 Seafood Ingestion 64

3.5 Special Considerations for C-14 EDC 65

4. DOSIMETRY AND HEALTH EFFECTS CONVERSION FACTORS 74

4.1 Analytical Treatment of Daughter Product Buildup During Environmental Transport 74
4.2 Dose Commitment Factors and Dose Rate Factors 75
4.3 Health Effects Conversion Factors 78
4.4 Revised Dosimetry and Risk Methodology 79

TABLE OF CONTENTS (continued)

Page

5. DISCUSSION OF VALUES FOR PARAMETERS 81

REFERENCES 97

NOMENCLATURE 102

APPENDIX A: Method for Consideration of Daughter Product Ingrowth 109

APPENDIX B: Dosimetry Factors 113

APPENDIX C: Sample Derivation of an Environmental Pathway Equation and Calculation of Population Health Effects 119

APPENDIX D: Health Effect per Curie Release Parameters 131

APPENDIX E: FORTRAN Listing of Computer Program 136

APPENDIX F: Sample Output of Computer Program 151

LIST OF TABLES

Page

S-1 Fatal Cancers per curie released for different release modes 9

1.2-1 Release modes and environmental pathways 13

3.5-1 Carbon-14 intergrated intake per unit deposition on the soil surface and the total body infinite environmental dose commitment per curie released to the river for the crop ingestion pathways 71

4.3-1 Health effects conversion factors 80

5-1 Radionuclide decay constants 84

5-2 Bioaccumulation factors for freshwater fish and seafood 87

5-3 Radionuclide intake factors 88

5-4 Leaching coefficients for radionuclides in soil 92

5-5 Distribution coefficients for radionuclides on sediment 94

B-1 Dosimetry factors 114

B-2 Source of dosimetry factors 117

C-1 Environmental dose commitment and fatal cancer calculations 130

D-1 Fatal cancers per curie released for different release modes 132

D-2 Fatal cancers per curie released for releases to a river 133

D-3 Fatal cancers per curie released for releases to an ocean 134

D-4 Fatal cancers per curie released for releases to a land surface 135

LIST OF FIGURES

		Page
2.1-1	Schematic diagram for transport of radionuclides from repository to river	17
2.1-2	Release rate to river as a function of time after placement of radioactive waste in repository . .	19
3.2.1-1	Compartment model for the ocean release mode . . .	38
3.3.3-1	Activity (mass) balance for soil element away from source	46
3.4.3.1-1	Compartment model for air over land-volcano/meteorite release mode	54
3.4.4.1-1	Compartment model for air-over-ocean-volcano/meteorite release mode.	62
C-1	Radionuclide travel from repository to river . . .	124

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SUMMARY

As part of its program to develop environmental standards for disposal of high-level radioactive wastes, the Environmental Protection Agency estimated population health risks for 10,000 years after disposal in mined geologic repositories (SmC82). This report describes the mathematical models we formulated to calculate the environmental dose commitments (EDC's) and population health effects (fatal cancers and first generation genetic defects) that could occur as a result of releases from such repositories. The report also identifies the data we chose to use in these models and presents our estimates of the premature fatal cancers caused per unit of radionuclide released to the environment. These estimates were used in selecting the containment requirements in the Agency's proposed disposal standards (47 FR 58196).

In performing these long-term assessments of population health effects, we recognize that it is pointless to try to make precise projections of the actual risks from repositories. Population distributions, food chains, living habits, and technological capabilities will undoubtedly change in major ways over 10,000 years. Unlike geological processes, they can be realistically predicted only for relatively short times. Accordingly, we formulated very general models of environmental pathways, and we assumed population sizes and characteristics similar to those of today. In particular, we usually avoided the detailed analytical techniques that would be appropriate for near-term environmental assessments of specific facilities.

The models described in this report consider risks to populations, as opposed to risks to individuals. Therefore, individual doses caused by potential releases from a repository cannot be determined from these analyses. However, a companion report (Go82) describes analyses that assess individual doses from several types of releases.

S.1 The Methodology

The Agency's performance assessments of geologic repositories (SmC82) identified four ways that radionuclides might be released to environmental pathways: to surface water (e.g., a river) through groundwater; to an ocean through surface water; to a land surface directly; or to multiple pathways after the very unlikely possibility of disruption by a volcano or a meteorite. For each of these four release modes, we modeled the ways that radionuclides can move through the geosphere and the biosphere to the population, and we estimated the intake by the population through each of these environmental pathways. We then calculated the EDC's per unit of each radionuclide released to the environment--for both internal and external dose pathways--using organ-specific dose commitment factors for bone, red marrow, lung, liver, GI-LLI, thyroid, kidney, ovaries, testes, and other soft tissue. (The "other soft tissue" EDC's were used to approximate all soft tissue EDC's not specifically listed.) Finally, we applied health effects conversion factors to the EDC's to estimate fatal cancers and first generation genetic effects per curie released to the environment.

Following the procedures for computing environmental dose commitments, we calculated the total health effects for the entire population exposed to the releases from a repository, rather than terminate the calculation at some arbitrary distance from the repository. A time integration was performed to sum the health effects from the time the repository is sealed ("disposal") until a specified time in the future (usually 10,000 years after disposal). The following sections summarize the procedures we used to calculate the population intake of radioactivity--or population EDC's for external exposures--for each of the four release modes. The population intakes of radioactivity for the internal pathways are converted to population EDC's by sequentially applying a dose conversion factor and a dose-to-risk conversion factor.

S.1.1 Releases to a River (Surface Water)

In the surface water release model, the repository containment is breached--after some initial period--and groundwater circulates through the repository into the surrounding geologic media and eventually to an aquifer. The aquifer then flows underground until it intersects a river. To determine the total release to the river, we developed and integrated an equation describing the release rate. The integrated form of the release equation was then used to compute integrated river water concentrations for use in the following environmental pathway models:

Drinking Water. We assumed that the population of interest receives drinking water from the river with no reduction in radionuclide concentrations due to water treatment. The intake rate for drinking water by an individual is combined with the ratio of the population drinking water to the river flow rate to obtain an estimate of the total intake of the radionuclide by the population per curie of the radionuclide released to the river.

Ingestion of Fish. We assume that fish caught in the river take up radioactivity from the water. By calculating the concentration of radionuclides in the fish and by multiplying by estimated fish ingestion rates by the population, we determined the total population intake, due to comsumption of fish, of the radionuclides released from the repository.

Ingestion of Food Raised on Irrigated Land. We assume that river water containing radionuclides from the repository is used to spray irrigate farm land by direct deposition onto the crops and the land surface below the crops. Furthermore, we assume that irrigated plants that have incorporated radionuclides through their leaves and root systems are consumed by humans as food--or are consumed by either dairy or beef cattle that transfer radionuclides to milk and meat. Ingestion rates of these various food products are used to estimate the total radionuclide intake by the population due to using river water for irrigation.

Inhalation of Resuspended Material. Some of the radionuclides deposited on the soil by irrigation are resuspended into the air. Using a resuspension factor and the integrated soil surface concentration, we estimated the resulting integrated concentration of radionuclides. We calculated the population intake of radionuclides using a standard inhalation rate and the size of the population.

External Exposure from Air Submersion. The radionuclides resuspended into the air can cause submersion exposures to the population. These EDC's are estimated, for each organ, from the integrated air concentration, the population density, an external dose factor, and a shielding and occupancy factor.

External Exposure from Ground Contamination. The radioactive material deposited on the ground during irrigation can also cause external exposures to persons in the area. Throughout the irrigation period, radionuclides continue to build up on the ground until either irrigation stops or equilibrium with losses through the soil is reached. The methods for estimating EDC's from this exposure are similar to those applied for the external exposure due to air submersion.

S.1.2 Releases to an Ocean

We assume that releases to a river system subsequently discharge into the ocean. Since we do not consider radionuclide decay during travel in the river or depletion of the radionuclide inventory due to river water use or sedimentation, the radionuclide releases to the ocean are identical to the releases to a river. Our model of the ocean pathway has two compartments: a shallow upper layer in which it is assumed that all edible seafood is grown and a lower layer that includes the remainder of the ocean. We developed coupled differential equations whose solutions express the quantities of radionuclides in these two compartments. The equation for the upper compartment inventory was divided by the volume of the compartment to determine the time-dependent concentation of radionuclides in the upper layer. This concentration was then used to estimate the amount of radioactivity taken up by the ocean fish and shellfish consumed by the population.

S.1.3 Releases Directly to Land Surface

For the land surface pathway models, we assume that some of the radioactive waste from the repository is brought to the surface after an event such as inadvertant intrusion while drilling for resources. Such releases to the surface are assumed to be over a small area and a short period of time--so that they can be modeled as instantaneous point sources. The mechanisms distributing the material to humans are resuspension and subsequent dispersion in the atmosphere. When the initial release to the land surface is determined, a time-dependent release rate to the air is estimated using a simple exponential model that depletes the land surface source to account for resuspension and radioactive decay. This release rate is applied in conjunction with an atmospheric dispersion equation to predict air concentrations as a function of time and distance from the source; these air concentrations are then used to estimate ground surface concentrations as a function of time and distance. Once ground surface concentrations are determined, the techniques used to calculate population intake are similar to those described for the river release mode. The pathways considered for releases to land surface are: (1) ingestion of food raised on land contaminated with radionuclides, including food crops, milk, and meat; (2) inhalation of resuspended radionuclides; (3) external exposure due to air submersion; and (4) external exposure due to ground contamination.

S.1.4 Releases Due to a Volcanic Eruption or Meteorite Impact

Releases caused by the extremely unlikely events of disruption by volcanoes or meteorites can be to the land surface and directly to the air. For the material released to the land surface, we used the methodology described for the land surface release mode. For the material released to the air, we assume that the radioactivity would be quickly dispersed in such a manner that it would eventually be distributed uniformly within the troposphere. The airborne material is divided into the fraction over land and the fraction over water--using the ratio of earth land surface and earth water surface. We then used compartment models, with their systems of coupled differential equations, to estimate the quantity of radionuclides reaching the land surface or ocean. Finally, we estimated the amount of radioactivity or radiation exposure reaching people through the same pathways described for the land surface or the ocean, respectively.

S.2 Results

The specific equations used for each of the steps in the methodology discussed above, and the parameters used in our current application of this methodology, are presented in the body of this report. Appendix D of the report describes the detailed results of our assessment, indicating the population health effects estimated--per curie released to the environment--for each of the environmental pathways considered under each release mode (a total of 30 pathways). The following table displays the total health effect (fatal cancer) per curie released values calculated for each of the four release modes. The most stringent of these sets of values--that for surface water--was used in calculating the release limits for the containment requirements of the Agency's proposed disposal standards (EPA82).

TABLE S-1:
Fatal cancers per curie released for different release modes

Nuclide	Releases to a River (Surface Water)	Releases to an Ocean	Releases to Land Surface	Releases due to Violent Interactions*
C-14	4.58 E- 2	1.12 E- 7	2.58 E- 5	7.65 E- 2
Ni-59	6.80 E- 4	6.74 E- 5	1.10 E- 5	1.23 E- 4
Sr-90	1.21 E- 1	1.91 E- 6	9.75 E- 4	1.63 E- 2
Zr-93	6.94 E- 2	5.74 E- 6	1.82 E- 1	1.55 E- 1
Tc-99	2.85 E- 4	1.04 E- 6	6.03 E- 8	3.67 E- 5
Sn-126	1.20 E- 1	7.86 E- 6	4.13 E- 2	1.12 E- 1
I-129	1.08 E- 2	9.62 E- 5	2.31 E- 5	1.38 E- 3
Cs-135	3.81 E- 3	1.58 E- 5	4.01 E- 4	7.36 E- 4
Cs-137	1.98 E- 2	1.60 E- 5	5.62 E- 4	6.91 E- 3
Sm-151	1.17 E- 4	1.38 E- 6	2.89 E- 6	1.64 E- 5
Ra-226	3.16	1.49 E- 2	8.42 E- 2	4.87 E- 1
U-234	1.33	1.38 E- 3	5.70 E- 1	6.13 E- 1
Np-237	5.96 E- 1	2.44 E- 3	3.22 E- 3	8.03 E- 2
Pu-238	2.29 E- 2	2.38 E- 5	3.21 E- 3	1.47 E- 2
Pu-239	6.92 E- 2	1.31 E- 4	5.55 E- 2	5.18 E- 2
Pu-240	6.53 E- 2	1.15 E- 4	4.94 E- 2	4.76 E- 2
Am-241	7.19 E- 1	1.19 E- 2	8.98 E- 2	1.59 E- 1
Pu-242	6.76 E- 2	1.30 E- 4	5.63 E- 2	5.13 E- 2
Am-243	2.68	8.81 E- 2	1.03	1.14

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*For example, interaction of a meteorite or a volcano with a repository.

Section 1: INTRODUCTION

1.1 Background Information

This report describes the methodology used to estimate future health effects to populations due to radionuclides that escape to the environment from a waste repository.* Mathematical models for estimating these health effects are proposed. An estimate of the fatal cancers per curie release for several radionuclides is needed for use in setting curie release limits in EPA's high-level waste standard and these estimates are given in Appendix D.

We obtained population health effects estimates by calculating the population environmental dose** commitment (EDC) and then multiplying it by a health effect conversion factor. Since the EDC is needed to estimate population health effects, most of the equations in this report express environmental dose commitment to the population. The conversion from EDC to population health effects is a very simple calculation and is discussed in more detail in Section 4.

The EDC is identical to collective dose commitment, S, as used in ICRP Publication 26, "Recommendations of the International Commission on Radiological Protection" (ICRP77) and the report entitled "Sources and Effects of Ionizing Radiation" (UN77). In this report, S_{nop} denotes the

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*Unless we state otherwise, we are estimating "excess" health effects, i.e., those caused by elevating radiation levels and in addition to those from other causes.

**For simplicity, the term "dose" will be used to denote "dose equivalent."

EDC, where the subscripts indicate that S is a function of nuclide, organ, and environmental pathway.* Mathematically, the EDC is expressed as

$$S_{nop} = \int_0^\infty \int_0^\infty D'(t)\, N(D',t)\, dD'dt \qquad (1.1\text{-}1)$$

where D'(t) is the dose commitment rate as a function of time and N(D',t) is the number of people exposed to dose commitment rate D'(t) at time t. The incomplete collective dose commitment, $S_{nop}(t)$, is defined as follows:

$$S_{nop}(t) = \int_0^t \int_0^\infty D'(t) N(D',t)\, dD'dt \ . \qquad (1.1\text{-}2)$$

The term "dose commitment rate" as used here means the 50-year dose commitment to individuals due to intake for one year in the case of internal emitters, or, in the case of external exposure, simply the annual dose.

In this assessment, the population of interest is the world population, which is assumed to be constant over the time period, t. Specifically, we assume that

$$\int_0^\infty N(D',t)dD' = N(t) = 10^{10} \text{ persons (UN77).} \qquad (1.1\text{-}3)$$

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*The variables used in the equations in this report are defined in the nomenclature, p. 102 ff.

Two EPA reports, besides this one, discuss dosimetry and health risk analysis for the EPA high-level waste standard. These reports cover individual dose assessment (Go82) and population risk assessments for setting high-level waste disposal standards (SmC82). The draft environmental impact statement (EPA82) and the individual dose assessment report (Go82) discuss individual dose rates. The population risk assessment report (SmC82) discusses risk assessments used to determine repository release limits for inclusion in the EPA standard.

1.2 Pathways Considered

These analyses consider four general modes of radionuclide releases from a waste repository: releases to a river, to an ocean, to a land surface, and from a volcanic or meteorite interaction with a waste repository. The releases to a river, an ocean, or a land surface can be caused by any number of events. For example, drilling a mining borehole through a repository could allow groundwater to leach radionuclides from the radioactive waste. The radionuclides could be transported to a river and subsequently to an ocean. A variation of this scenario would be radionuclide releases directly to the land surface by a drilling event. Volcanic eruption or meteorite impact have a lower probability of occurrence than those events discussed above. This class of events generally results in violent release of radioactive material directly to the land surface and to the air. These four release modes are subdivided into a total of 30 pathways, as listed in Table 1.2-1.

TABLE 1.2-1
Release modes and environmental pathways

Release Mode	Pathways Included in this Release Mode	Pathway Number
Releases to River	Drinking Water Ingestion	1
	Freshwater Fish Ingestion	2
	Food Crops Ingestion	3
	Milk Ingestion	4
	Beef Ingestion	5
	Inhalation of Resuspended Material	6
	External Dose-Ground Contamination	7
	External Dose-Air Submersion	8
Releases to Ocean	Ocean Fish Ingestion	9
	Ocean Shellfish Ingestion	10
Releases Directly to Land Surface	Food Crops Ingestion	13
	Milk Ingestion	14
	Beef Ingestion	15
	Inhalation of Resuspended Material	12
	External Dose-Ground Contamination	16
	External Dose-Air Submersion	11
Releases Due to Volcano/ Meteorite Interaction		
Releases Directly to Land	Food Crops Ingestion	25
	Milk Ingestion	26
	Beef Ingestion	27
	Inhalation of Resuspended Material	24
	External Dose-Ground Contamination	28
	External Dose-Air Submersion	23
Releases to Air Over Land	Food Crops Ingestion	19
	Milk Ingestion	20
	Beef Ingestion	21
	Inhalation of Dispersed and Resuspended Material	17
	External Dose-Ground Contamination	22
	External Dose-Air Submersion	18
Releases to Air Over Ocean	Ocean Fish Ingestion	29
	Ocean Shellfish Ingestion	30

1.3 Approach to Calculations

The goal of the analysis for each specific pathway is to estimate the EDC to specific organs per unit nuclide released to the accessible environment (normalized EDC's) in order to determine population health effects. The organs for which EDC's are calculated are bone, red marrow, lung, liver, GI-LLI, thyroid, kidney, other soft tissue,* ovaries, and testes.

After the normalized values are determined as a function of nuclide, organ, and pathway, a summation over pathways may be performed. The result is normalized EDC's, for a release mode, which are a function of nuclide and organ. With this approach, these normalized EDC's can be used to predict the total EDC for various scenarios which lead to releases to the biosphere from a repository, without a "reanalysis" for each new event.

Developing pathway computation models involves applying the mechanisms for leakage of radionuclides from a repository and predicting the processes which cause these radionuclides to disperse in the environment. These models and methods are discussed in more detail in Sections 2 and 3. In general, the pathway equations integrate the doses over all persons exposed from the time the material is placed in the repository until time, t, in the future to yield the incomplete environmental dose commitment.

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*Total body dosimetry factors are applied for other soft tissue since dosimetry factors for muscle (the standard factors applied for other soft tissue) were not available in many of the references we consulted.

Section 2: SOURCE TERMS

We use simple transport models to estimate the movement of radionuclides from the repository into the accessible environment. Different scenarios are applied in developing the source term models for the four release modes. For some of the release modes, several different mathematical models for determining releases to the environment are possible. In this report, only one release model has been addressed for each release mode. The environmental pathway calculations for other release models would be treated in a manner similar to the methods discussed in this report. A more complete discussion of source terms is included in the population risk assessment report (SmC82).

2.1 River Source Terms

For the river pathway, we assume the radionuclides remain in the repository for the initial delay period, t_{er}, following placement.* After this time, we assume that the repository is breached and that radionuclides can be removed from the repository and eventually be transported to a river. There are several different mechanisms which determine the rate of removal of radionuclides from a repository such as their susceptibility to leaching, water flow through the repository, solubility of the chemical compound containing the radionuclides, waste heat from the buried waste, and type of event causing the release. The methods for obtaining the specific releases for a release scenario are discussed in the population risk assessment report (SmC82). In this report, we use a radionuclide removal model limited by the rate of leaching to illustrate typical river environmental transport equations. Several other release models are plausible, but this "leaching-limited" model has been chosen because it is reasonably simple and leads to closed-form environmental pathway equations.

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*The variables used in this report are defined in the nomenclature, p. 102 ff.

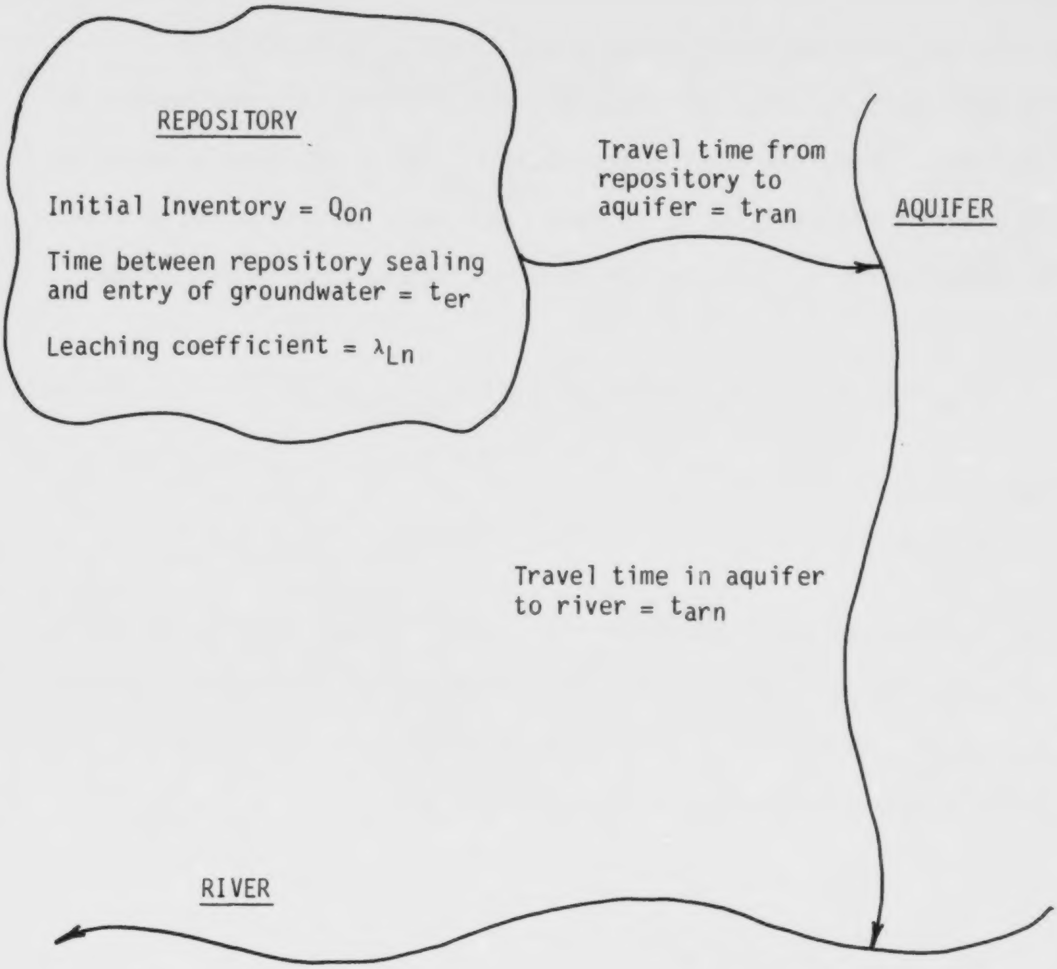
The total human intake for each river pathway is taken to be proportional to the total quantity (i.e., the integrated concentration) of the radionuclide in the river. Therefore, the time-dependent rate of entry of radionuclides to the river must be developed so that it can be integrated. We assume that the repository is breached and ground water circulates through the repository and leaches radionuclides into the surrounding area and eventually to an aquifer after passage of additional time, t_{ran}. The radionuclide-specific source term equation that describes the time-dependent rate of entry of each radionuclide (n) into the aquifer, $Q'_{anp}(t)$, is expressed as (see Fig. 2.1-1)

$$Q'_{anp}(t) = \lambda_{Ln}\, f_L\, Q_{on} \exp\left[-\lambda_{Dn}t - \lambda_{Ln}(t-t_{er}-t_{ran})\right] \qquad \text{for } t>t_{er}+t_{ran}$$

$$\text{and} \qquad (2.1\text{-}1)$$

$$Q'_{anp}(t) = 0 \qquad \text{for } t \le t_{er}+t_{ran}.$$

The aquifer flows underground for a representative distance until it intersects a river system. Radionuclides entering the aquifer are assumed to reach the river after a delay time, t_{arn}. The equation for radionuclide release rate to a river is simply the previously presented


REPOSITORY
Initial Inventory = Q_{on}
Time between repository sealing and entry of groundwater = t_{er}
Leaching coefficient = λ_{Ln}
Travel time from repository to aquifer = t_{ran}
AQUIFER
Travel time in aquifer to river = t_{arn}
RIVER

(Note: $t_{rn} = t_{er} + t_{ran} + t_{arn}$ = time between sealing of repository and entry of radionuclides into the river.)

Fig. 2.1-1. Schematic diagram for transport of radionuclides from repository to river

source term for radioactivity entering the aquifer (equation 2.1-1) corrected to account for the additional time (t_{arn}) required to transport each radionuclide from the point of entry into the aquifer to the river. Thus, the river source term $Q'_{np}(t)$ is the rate of entry to the river of radionuclide n, in curies per year, as a function of time. The equation for $Q'_{np}(t)$ for the leaching-limited case is as follows:

$$Q'_{np}(t) = \lambda_{Ln}\, f_L\, Q_{on}\, \exp[-\lambda_{Dn}t-\lambda_{Ln}(t-t_{er}-t_{ran}-t_{arn})] \qquad \text{for } t>t_{er}+t_{ran}+t_{arn} \tag{2.1-2}$$

and

$$Q'_{np}(t) = 0 \qquad \text{for } t\leq t_{er}+t_{ran}+t_{arn}.$$

Fig. 2.1-2 shows the exponential shape of the release rate to the river.

In later calculations, we will need the total (integrated) amount, $Q_{np}(t)$, of radionuclide n that has entered the river up to time t. This quantity can be determined using the equation

$$Q_{np}(t) = \int_0^t Q'_{np}(t)\, dt. \tag{2.1-3}$$

Substituting equation 2.1-2 into equation 2.1-3 and integrating, we obtain:

$$Q_{np}(t) = \frac{f_L\lambda_{Ln}Q_{on}}{\lambda_{Dn}+\lambda_{Ln}} \begin{bmatrix} \exp[-\lambda_{Dn}t_{Rn}] \\ -\exp[\lambda_{Ln}t_{Rn} -(\lambda_{Dn}+\lambda_{Ln})t] \end{bmatrix} \qquad \text{for } t>t_{Rn} \tag{2.1-4}$$

and

$$(t_{Rn} = t_{er} + t_{ran} + t_{arn})$$

$$Q_{np}(t) = 0 \qquad \text{for } t\leq t_{Rn}\ .$$

Once the source term to the river is determined, we can calculate radionuclide concentrations in the river. These calculations are discussed in Section 3.1

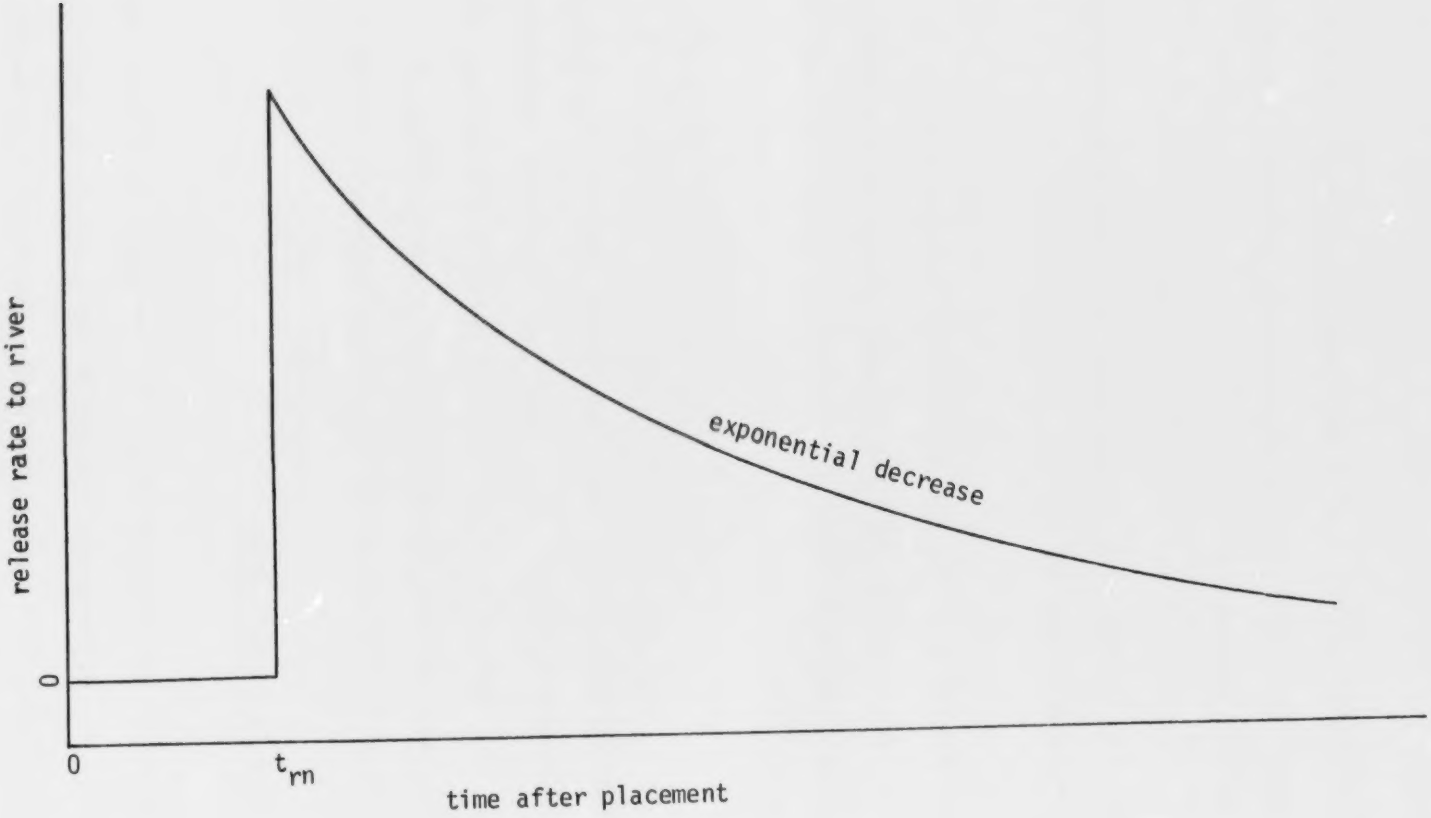


Figure 2.1-2. Release rate to river as a function of time after placement of radioactive waste in repository

2.2 Ocean Source Terms

For the ocean pathway models, we assume that radionuclides from a waste disposal facility reach the ocean only by transport through a river system. We also assume that

- travel time in the river to the ocean is so small that radionuclide decay may be neglected; and
- it is acceptable to neglect depletion of radionuclides in the river due to removal by irrigation and sedimentation (this assumption leads to a conservative estimate of the quantity of radionuclides reaching the ocean since irrigation and sedimentation will remove a portion of the radionuclides in the river).

In light of these assumptions, the source terms for the ocean and river releases are the same. The release rate and total integrated release for the ocean release mode for the leaching-limited case are given by equations 2.1-2 and 2.1-4, respectively. The computation of radionuclide concentrations in the ocean is discussed in Section 3.2.

2.3 Land Surface Source Terms

For the river and ocean release mode, the source term model employed predicts a continuous long-term release of radionuclides to the biosphere after leakage begins at a waste repository. The events hypothesized for the land surface release mode are those which could cause radionuclides from the repository to be brought directly to the earth's surface, in a short time period, such as drilling a well into or through a waste repository. We assume that these events result in an instantaneous release of some fraction, f_{LS}, of the contents of the repository to the land surface at a time, t_L, after emplacement of waste in a repository. The release is assumed to be to a small area of land, which can be considered as a point source for calculation of the resuspension from ground to air and the subsequent redistribution in the environs. The EDC pathway analyses for the land surface release mode are discussed in Section 3.3.

2.4 Volcano/Meteorite Interaction Source Terms

We assume that a violent volcanic eruption or a meteorite impact liberates materials from the repository in a short time. A fraction, f_{LL}, of this material goes directly to the land surface and the rest is released directly to the air. That released to the land surface is conservatively assumed to be distributed in a small area, and the mechanisms for treating the redistribution of this material in the environment are the same as those used for the land surface release. We assume that the material released to the air is dispersed in such a manner that it is, eventually, distributed uniformly in the troposphere. The airborne material is divided into the fraction over land, f_{AL}, and the fraction over water, f_{AW}, using the ratio of earth land surface area to total earth area and earth water surface area to total earth area.

The methodology used to predict distribution of radionuclides in the environment and to analyze the EDC pathways for the volcano/meteorite release mode are discussed in Section 3.4.

Section 3: ENVIRONMENTAL TRANSPORT AND DOSIMETRY MODELS

This section contains the specific mathematical models used to calculate environmental dose commitment (EDC) and possible health effects for each pathway and a discussion of the rationale for each model.* The sources of the data used in applying the models are discussed in Sections 4 and 5.

The models used in these analyses are simple but we believe they are appropriate for setting generally applicable environmental standards. There is a large amount of uncertainty in some of the parameters. For this reason, it would not be appropriate to apply more sophisticated models. When possible, the end results of existing, more detailed model evaluations are used.

The definition of terms for the equations in the sections to follow are given in the "Nomenclature" except where a term is used only locally in a section. In those instances, the terms may be defined in the sections where they are used.

In the following sections, the equations which are discussed are for the normalized population environmental dose commitment (EDC) per unit of radionuclide release to the accessible environment for the 30 pathways. For all pathways, we calculate the possible fatal cancers and first generation genetic effects* per unit of radioactivity release. This is done by multiplying each normalized organ specific EDC, S_{nop}/Q_{np}, by the appropriate organ specific fatal cancer or genetic health effects conversion factor, $HECON_o$. The organs used to compute fatal cancers are bone, red marrow, lung, liver, GI-LLI, thyroid, kidney, and other soft tissue. The organs used to compute first generation genetic effects are ovaries and testes. Once either fatal cancers or genetic effects are determined for the applicable organs, the health effects for the various organs may be summed to obtain health effects as a function of nuclide and pathway. Finally, the health effects for the various pathways within a release mode may be summed to obtain health effects per unit release of each specific radionuclide by that pathway. The mathematical formulation for this process can be written for fatal cancers as

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*The variables used in the equations in this report are defined in the nomenclature, p. 102 ff.

$$\frac{FHE}{Q_n} = \sum_{o=1}^{8} \sum_{p} \frac{S_{nop}}{Q_{np}} (HECON_o) \qquad (3.1\text{-}1)$$

and for first-generation genetic effects as

$$\frac{GE}{Q_n} = \sum_{o=9}^{10} \sum_{p} \frac{S_{nop}}{Q_{np}} (HECON_o) \qquad (3.1\text{-}2)$$

where the summation over pathways (p) extends over the number of pathways considered in a release mode.

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*First generation genetic effects are the genetic effects to the children of the generation exposed to the radiation.

3.1 Releases to a River

3.1.1 General Considerations

The methods for determining the release of radionuclides from the repository to the river are discussed in Section 2.1. Using these releases, the radionuclide concentrations in the river are computed by dividing the average yearly radionuclide source terms by the average river flow rate. Radionuclides from the river expose the local population through drinking water, ingestion of freshwater fish, irrigation pathways (including ingestion of food crops, milk, and beef) inhalation of resuspended radioactivity, and direct radiation dose from ground surfaces and from air. These specific pathways are discussed below.

3.1.2 Drinking Water Ingestion [pathway number (p) = 1]

The annual dose to an individual is given by the product of the amount of water he drinks (I_w), the radionuclide concentration (Q'_{np}/R), and the dose conversion factor (D_{nop}) in the equation:

$$DI'_{nop} = \frac{Q'_{np} \, I_w \, D_{nop}}{R} . \qquad (3.1.2\text{-}1)$$

The annual population dose can be expressed as the annual individual dose multiplied by the number of persons drinking the water, or

$$S'_{nop} = DI'_{nop} \, P_R = \frac{Q'_{np} \, I_w \, D_{nop} \, P_R}{R} . \qquad (3.1.2\text{-}2)$$

By integrating the above expression over time we obtain

$$S_{nop} = \frac{Q_{np} \; I_w \; D_{nop} \; P_R}{R} \qquad (3.1.2\text{-}3)$$

where

$$\int_0^t S'_{nop} \; (t) \; dt = S_{nop} \qquad (3.1.2\text{-}4))$$

and

$$\int_0^t Q'_{np}(t) \; dt = Q_{np} \; . \qquad (3.1.2\text{-}5)$$

Upon dividing both sides of equation 3.1.2-3 by the integrated release to the river, Q_{np}, we obtain

$$\frac{S_{nop}}{Q_{np}} = \frac{P_R \; I_W \; D_{nop}}{R} \; . \qquad (3.1.2\text{-}6)$$

This equation applies to drinking water obtained from rivers. In practice, drinking water could come from rivers, lakes, and wells, and the population EDC could result from leaching of radionuclides into all of these sources. However, we assume that repositories are sited far enough away from ground water supplies to preclude the contamination of drinking water for significant populations. For the long time periods chosen for this analysis, lake and river water concentrations will become equal. Thus, we believe that restricting our analysis to river water will be a completely adequate basis for our calculations.

After obtaining values for the parameters, equation 3.1.2-6 can be used to calculate the normalized EDC to the local population from the ingestion of river water. Parameter values are discussed in Sections 4 and 5.

The analysis does not include removing radionuclides by water treatment and by sedimentation from the river. Also, we assumed that the entire river is contaminated so that all persons obtaining drinking water from the river consume contaminated water. These are conservative assumptions.

3.1.3 Freshwater Fish Ingestion (p=2)

The annual dose to an individual is given by the amount of fish he eats (I_f), the radionuclide concentration in the river water (Q'_{np}/R), a concentration factor expressing the concentration of radionuclides in fish compared to the concentration in water (CF_{np}), and the dose conversion factor (D_{nop}):

$$DI'_{nop} = \frac{Q'_{np}\ CF_{np}\ I_f\ D_{nop}}{R}\ . \qquad (3.1.3\text{-}1)$$

The annual population dose can be expressed as the annual individual dose multiplied by the number of persons eating fish:

$$S'_{nop} = DI'_{nop}\ P_{FF} = \frac{Q'_{np}\ CF_{np}\ I_f\ D_{nop}\ P_{FF}}{R}\ . \qquad (3.1.3\text{-}2)$$

By integrating this expression over time we obtain

$$S_{nop} = \frac{Q_{np}\ CF_{np}\ I_f\ D_{nop}\ P_{FF}}{R} \qquad (3.1.3\text{-}3)$$

where the method for obtaining S_{nop} and Q_{np} is given in equations 3.1.2-4 and 3.1.2-5. Upon dividing both sides of equation 3.1.3-3 by the integrated release to the river, Q_{np}, we obtain

$$\frac{S_{nop}}{Q_{np}} = \frac{CF_{np}\ P_{FF}\ I_f\ D_{nop}}{R} \ . \qquad (3.1.3\text{-}4)$$

This equation is for freshwater fish from rivers, since we assume that all freshwater fish eaten by the population come from rivers. Similar to the drinking water pathway, this assumption allows us to ignore additional pathways for fish consumption associated with lakes. Using the data discussed in Sections 4 and 5, equation 3.1.3-4 can be used to calculate the EDC to the local population from ingestion of freshwater fish.

3.1.4 Food Ingestion

Food crops (p=3)
Milk (p=4)
Beef (p=5)

The annual dose to an individual from consuming foods raised on irrigated land is a product of the concentration of radionuclides in the river water (Q'_{np}/R), the irrigation rate (W), a conversion factor to express the radionuclide intake by an individual per unit deposition to the ground surface (RI_{np}), and the dose conversion factor (D_{nop}):

$$DI'_{nop} = \frac{Q'_{np}\ W\ RI_{np}\ D_{nop}}{R} \ . \qquad (3.1.4\text{-}1)$$

The annual population dose can be expressed as the annual individual dose multiplied by the number of persons being fed a particular food crop raised on irrigated land. The size of the population eating irrigated food crops can be determined by multiplying the number of persons who can be fed by raising the food crop on a unit area of land (CP_p), the area of the irrigated land (A), and a weighting factor that expresses the fraction of irrigated land used for a particular crop (f_p):

$$P_{Fp} = CP_p \, A \, f_p \, . \qquad (3.1.4\text{-}2)$$

Then the annual population dose is

$$S'_{nop} = DI'_{nop} \, P_{Fp} = \frac{Q'_{np} \, W \, RI_{np} \, D_{nop} \, CP_p \, A \, f_p}{R} \, . \qquad (3.1.4\text{-}3)$$

By integrating this expression over time we obtain

$$S_{nop} = \frac{Q_{np} \, W \, RI_{np} \, D_{nop} \, CP_p \, A \, f_p}{R} \, . \qquad (3.1.4\text{-}4)$$

The ratio (W/R) is needed for each food pathway. We can write the relationship

$$WA = f_R R \qquad (3.1.4\text{-}5)$$

where A is the area of land irrigated (m^2).

Rearranging, we have

$$\frac{W}{R} = \frac{f_R}{A} \quad , \qquad (3.1.4\text{-}6)$$

which can be substituted into equation 3.1.4-4.

As mentioned previously, RI_{np} is the intake of radionuclide n by standard man for crop p for an acute deposition to the surface (Ci intake per Ci/m^2 deposited on the soil surface). Values for RI_{np} are listed in Section 5 and the equation used to determine values for RI_{np} for food crops is discussed in detail in Appendix C. The equations for the milk and meat pathway are similar to the equation for the food crops. The values were determined using the AIRDOS-EPA computer code (Mo79). Using this code, values of the human intake rate of radionuclides (Ci/yr) due to ingestion of produce and leafy vegetables, ingestion of milk, and ingestion of meat can be calculated. Also, the total deposition rate of these nuclides (Ci/m^2-yr) to the soil can be calculated. Thus, this output from AIRDOS-EPA was used to determine the values of RI_{np} for produce and leafy vegetables, milk, and meat by dividing the human intake rate by the total ground deposition rate. This yielded Ci/yr intake per Ci/m^2-yr deposited to the soil surface. The code was run for a long period of deposition to the soil surface so that equilibrium values of RI_{np} were obtained. It can be shown that the ratio of the equilibrium intake rate to a continuous deposition rate (Ci/day per Ci/m^2-day) is numerically equal to the ratio of the total integrated intake to the acute surface deposition (Ci per Ci/m^2). Thus, the values of RI_{np} determined using AIRDOS-EPA can be applied to determine the total intake of radionuclides by humans per Ci/m^2 deposited to the ground surface.

The mathematical models incorporated in AIRDOS-EPA are similar to those used by the U.S. Nuclear Regulatory Commission (NRC77). One significant change was made to these mathematical models before using the code to determine values for RI_{np}. The loss of radionuclides from the soil root zone was taken into account in computing uptake of radionuclides into plants through plant root systems. This loss mechanism from the soil was not addressed in either Regulatory Guide 1.109 (NRC77) or AIRDOS-EPA (Mo79) and can be important for long-lived radionuclides.

The values of RI_{np} are based on an air deposition rate; therefore, the results are appropriate only to spray irrigation. Doses associated with ditch irrigation will be overestimated since deposition to crop surfaces will be included. The only actual transfer mechanism for ditch irrigation is uptake by the crops from the soil. Most of the data used in

AIRDOS-EPA to calculate the values for RI_{np} are discussed in the code documentation (Mo79).

Substituting (f_R/A) for (W/R) in equation 3.1.4-4, the irrigation area, A, cancels out and we obtain the following expression for the EDC to the local population due to the ingestion of crops:

$$\frac{S_{nop}}{Q_{np}} = f_R \, f_p \, RI_{np} \, CP_p \, D_{nop} \; . \qquad (3.1.4\text{-}7)$$

As for the other river pathways, we assume that the entire river is contaminated so that all the irrigation water obtained from the river is also contaminated. This is a conservative assumption.

3.1.5 Inhalation of Resuspended Material (p=6)

The annual dose to an individual from inhalation occurs due to material being deposited on the ground surface by irrigation and subsequently resuspending from the ground surface into the air. This annual dose is the product of the air concentration (X_{Rn}), the inhalation rate of an individual (I_B), and the dose conversion factor (D_{nop}):

$$DI'_{nop} = X_{Rn} \, I_B \, D_{nop} \; . \qquad (3.1.5\text{-}1)$$

The annual population dose is the annual individual dose multiplied by the number of persons inhaling air containing radionuclides:

$$S'_{nop} = DI'_{nop} \, P_{Ap} \; . \qquad (3.1.5\text{-}2)$$

The number of persons subject to inhalation can be determined by multiplying the population density for the irrigation area by the size of the area:

$$P_{An} = PD_p\ A \tag{3.1.5-3}$$

Since the exposed population was confined to persons within the irrigation area, the implicit assumption for equation 3.1.5-3 is that the radioactive material deposited during irrigation remains on the ground or in the air above the irrigated ground. Although, in practice, radioactive material resuspended into air would be diluted and distributed over a wider area, our approach should yield approximately the same numerical population dose as the more exact and more complicated method of accounting for dispersion of radionuclides in the air beyond the irrigation area. Combining equations 3.1.5-1, 3.1.5-2 and 3.1.5-3 yields

$$S'_{nop} = X_{Rn}\ I_B\ D_{nop}\ PD_p\ A\ . \tag{3.1.5-4}$$

The air concentration, $X_{Rn}(t)$, at the center of a uniformly contaminated area having a surface concentration, $\phi_n(t)$, due to resuspension of radionuclides from the ground surface is shown by Nelson (Ne78) to be :

$$X_{Rn}(t) = RF\ \ \phi_n(t) \tag{3.1.5-5}$$

where

$$RF = X_{Rn}(t)/\phi_n(t) = \lambda_R/v_{gn}\ . \tag{3.1.5-6}$$

RF is the ratio of air concentration to soil surface concentration.

Equation 3.1.5-6 holds if the radius of the ground surface source term is large compared to the depletion distance for material resuspended to the air (i.e., this approximation is only valid for large, uniformly contaminated areas). We assume that redistribution of materials by resuspension in the contaminated area is inconsequential, which is equivalent to saying that the resuspended air concentration at a point in the contaminated area only depends on the soil surface concentration at the point of interest.

Substituting equation 3.1.5-5 into equation 3.1.5-4 yields

$$S'_{nop} = RF\ \phi_n(t)\ I_B\ D_{nop}\ PD_p\ A\ . \qquad (3.1.5\text{-}7)$$

By integrating equation 3.1.5-7 over time, we obtain the following expression for the inhalation pathway environmental dose commitment:

$$S_{nop} = RF\left[\int_0^t \phi_n(t')\ dt'\right] I_B\ D_{nop}\ PD_p\ A\ . \qquad (3.1.5\text{-}8)$$

The soil surface radionuclide concentration as a function of time, ϕ (t), is calculated by solving the differential equation

$$\phi'_n(t) = -(\lambda_{Dn} + \lambda_{Sn})\ \phi_n(t) + \frac{W}{R}\ Q'_{np}(t)\ , \qquad (3.1.5\text{-}9)$$

where $\phi'_n(t)$ is the rate of change with time of the soil surface concentration for radionuclide n; λ_{sn} is the removal constant from the soil surface to the soil sink; and the other terms have been previously defined.

The term $-(\lambda_{Dn} + \lambda_{sn})\ \phi_n(t)$ represents the rate of removal of radionuclide n from the ground surface, and the term (W/R) $Q'_{np}(t)$ represents the rate of deposition of radionuclide n to the ground surface by irrigation.

The basic assumption in the expression $\phi'_n(t)$ is that removal of radionuclides from the ground surface by resuspension, $\lambda_R\ \phi_n(t)$, is offset by deposition to the ground surface of the resuspended material, $X_{Rn}(t)\ v_{gn}$. Thus these terms do not appear in equation 3.1.5-9. This assumption should be adequate for a large distributed source. Substituting f_R/A for W/R as before, we can solve the differential equation 3.1.5-9 to obtain the expression for the soil surface concentration, which is

$$\phi_n(t) = \frac{\lambda_{Ln} f_L Q_{on} f_R}{A(\lambda_{Ln}-\lambda_{Sn})} \begin{bmatrix} \exp\left[\lambda_{Sn} t_{Rn} - (\lambda_{Dn}+\lambda_{Sn})t\right] \\ -\exp\left[\lambda_{Ln} t_{Rn} - (\lambda_{Dn}+\lambda_{Ln})t\right] \end{bmatrix} \qquad \text{for } t > t_{Rn}$$

and (3.1.5-10)

$$\phi_n(t) = 0 \qquad \text{for } t \leq t_{Rn}$$

where, again: $t_{Rn} = t_{er} + t_{ran} + t_{arn.}$,

As discussed in Section 2.1, this equation is based on a leach-rate limited release model, which is only one of several release models considered by EPA. The method used to address resuspension is based on Nelson's (Ne78) assumptions; however, resuspension is addressed in a direct manner rather than using Nelson's method. The results of both methods should be identical. Substituting equation 3.1.5-10 into equation 3.1.5-8 and integrating, the resulting equation can be used to calculate the EDC to the local population due to inhalation of resuspended material from the ground surface. If one factors out the integrated source term, Q_{np}, expressed in equation 2.1-4, the resulting equation for EDC per unit release to the river for inhalation of resuspended material becomes

$$\frac{S_{nop}}{Q_{np}} = \frac{RF\ PD_p I_B D_{nop} f_R}{(\lambda_{Ln} - \lambda_{Sn})} \left\{ \frac{(\lambda_{Dn} + \lambda_{Ln}) \left[e^{-\lambda_{Dn} t_{Rn}} - e^{[\lambda_{Sn} t_{Rn} - (\lambda_{Dn} + \lambda_{Sn})t]} \right]}{(\lambda_{Dn} + \lambda_{Sn}) \left[e^{-\lambda_{Dn} t_{Rn}} - e^{[\lambda_{Ln} t_{Rn} - (\lambda_{Dn} + \lambda_{Ln})t]} \right]} - 1 \right\}$$

$$\text{for } t > t_{Rn} \qquad (3.1.5\text{-}11)$$

and

$$\frac{S_{nop}}{Q_{np}} = 0 \qquad \text{for } t \leq t_{Rn}\ .$$

Note that the irrigation area cancels out of equation 3.1.5-11.

3.1.6 External Dose - Ground Contamination (p=7)

The derivation of an expression for environmental dose commitment for material deposited on the ground surface is similar to the derivation for the inhalation pathway. The equation is

$$S_{nop} = [PD_p \cdot A] \int_0^t \phi_n(t')dt' \cdot [D_{nop} \cdot SOF] \qquad (3.1.6\text{-}1)$$

where D_{nop} is the external dose conversion factor for ground surface contamination in rem/yr per Ci/m^2; SOF is a shielding factor that accounts for the reduction in external dose due to household shielding and occupancy; and the other terms have been previously defined or appear in the "Nomenclature" section. Using equation 3.1.5-10, the integrated ground concentration is given by

$$\int_0^t \phi_n(t')dt' = \frac{\lambda_{Ln} f_L Q_{on} f_R}{(\lambda_{Ln}-\lambda_{Sn})A} \left\{ \frac{\exp[-\lambda_{Dn}t_{Rn}] - \exp[\lambda_{Sn}t_{Rn}-(\lambda_{Dn}+\lambda_{Sn})t]}{\lambda_{Dn}+\lambda_{Sn}} + \frac{\exp[\lambda_{Ln}t_{Rn} - (\lambda_{Dn}+\lambda_{Ln})t] - \exp[-\lambda_{Dn}t_{Rn}]}{\lambda_{Dn}+\lambda_{Ln}} \right\}$$

$$\text{for } t > t_{Rn} . \qquad (3.1.6\text{-}2)$$

Substituting the above equation into equation 3.1.6-1, and normalizing by the integrated source term to time t using equation 2.1-4, one obtains the following expression for the EDC to a local population due to direct exposure from radionuclide n deposited on the ground surface:

$$\frac{S_{nop}}{Q_{np}} = \frac{f_R\ PD_p\ D_{nop}\ SOF}{(\lambda_{Ln}-\lambda_{Sn})} \left\{ \frac{(\lambda_{Dn}+\lambda_{Ln}) \left[e^{-\lambda_{Dn}t_{Rn}} - e^{[\lambda_{Sn}t_{Rn}-(\lambda_{Dn}+\lambda_{Sn})t]}\right]}{(\lambda_{Dn}+\lambda_{Sn}) \left[e^{-\lambda_{Dn}t_{Rn}} - e^{[\lambda_{Ln}t_{Rn}-(\lambda_{Dn}+\lambda_{Ln})t]}\right]} - 1 \right\}$$

$$\text{for } t > t_{Rn}$$

and

$$\frac{S_{nop}}{Q_{np}} = 0 \qquad \text{for } t \le t_{Rn} . \qquad (3.1.6\text{-}3)$$

3.1.7 External Dose - Air Submersion (p=8)

The procedure for developing an equation to predict EDC from external dose due to air submersion follows a rationale very similar to that for the EDC for external dose due to ground contamination. The variation from the procedure described in Section 3.1.6 is that a resuspension factor, RF, is added to equation 3.1.6-1 to predict integrated air concentration due to resuspension, based on the concentration of radionuclides on the ground, and the dose factor takes units of rem/yr per Ci/m^3, i.e.:

$$S_{nop} = [RF\ PD_p\ A] \int_0^t \phi_n(t')dt'\ [D_{nop}\ SOF] \ . \qquad (3.1.7\text{-}1)$$

After substituting equation 3.1.6-2 for the integral in equation 3.1.7-1 and normalizing by the integrated source term, one obtains the following expression for the EDC to a local population due to direct exposure from radionuclide n in the air:

$$\frac{S_{nop}}{Q_{np}} = \frac{RF\ f_R PD_p D_{nop} SOF}{(\lambda_{Ln} - \lambda_{Sn})} \left\{ \frac{(\lambda_{Dn}+\lambda_{Ln}) \left[e^{-\lambda_{Dn} t_{Rn}} - e^{[\lambda_{Sn} t_{Rn} - (\lambda_{Dn}+\lambda_{Sn})t]} \right]}{(\lambda_{Dn}+\lambda_{Sn}) \left[e^{-\lambda_{Dn} t_{Rn}} - e^{[\lambda_{Ln} t_{Rn} - (\lambda_{Dn}+\lambda_{Ln})t]} \right]} - 1 \right\}$$

$$\text{for } t > t_{Rn} \qquad (3.1.7\text{-}2)$$

and

$$\frac{S_{nop}}{Q_{np}} = 0 \qquad \text{for } t \le t_{Rn}.$$

3.2 Releases to an Ocean *

3.2.1 General Considerations

This section describes the calculation of partial environmental dose commitments to a given organ, o, as the result of exposure to high-level waste radionuclides in the ocean, specifically for the case of a leaching-rate-limited source term where radionuclides from a geological

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* The variables used in the equations in this section are defined in the "Nomenclature" section, p. 102 ff.

repository reach the ocean through rivers. The model employed for these ocean pathway calculations is illustrated in Fig. 3.2.1-1. The model includes two compartments. Compartment 1 is the upper mixed layer of the ocean and compartment 2 is the lower layer (the remainder) of the ocean. Radionuclide n enters the upper layer from the river and leaves this layer by transport to the lower layer (γ_1), by radioactive decay (λ_{Dn}) and by sedimentation (SF_{1n}). Radionuclide n is returned to the upper layer by back-transport from the lower layer (γ_2). Radionuclide n enters the lower layer by transport from the upper layer (γ_1) and by sediment passing from the upper to lower layer (SF_{1n}) and is removed by decay (λ_{Dn}), by back-transport to the upper layer (γ_2), and by sedimentation (SF_{2n}).

Several basic assumptions are made in deriving this model. First, the input to the ocean is taken to be of the form $A_1\exp(\omega_n t)$, which is assumed to equal the input into the river (equation 2.1-2) from a repository with no reductions of input by decay during travel, by irrigation, or by sedimentation. The reason these assumptions were made was to allow releases directly to an ocean to be evaluated without considering the effects of various removal mechanisms in a river system. Second, the two compartment model used is a simplification since the actual transport from the upper mixed layer to the lower layer is diffusion controlled. In this model, we assume that both layers are fully mixed. This will lead to a discontinuity in concentration at the boundary between the two layers. Third, fish and shellfish ingestion are considered to be the only non-negligible routes of radiation uptake and exposure to humans via the ocean pathway. Fourth, all edible fish and shellfish are assumed to be taken from the upper compartment.

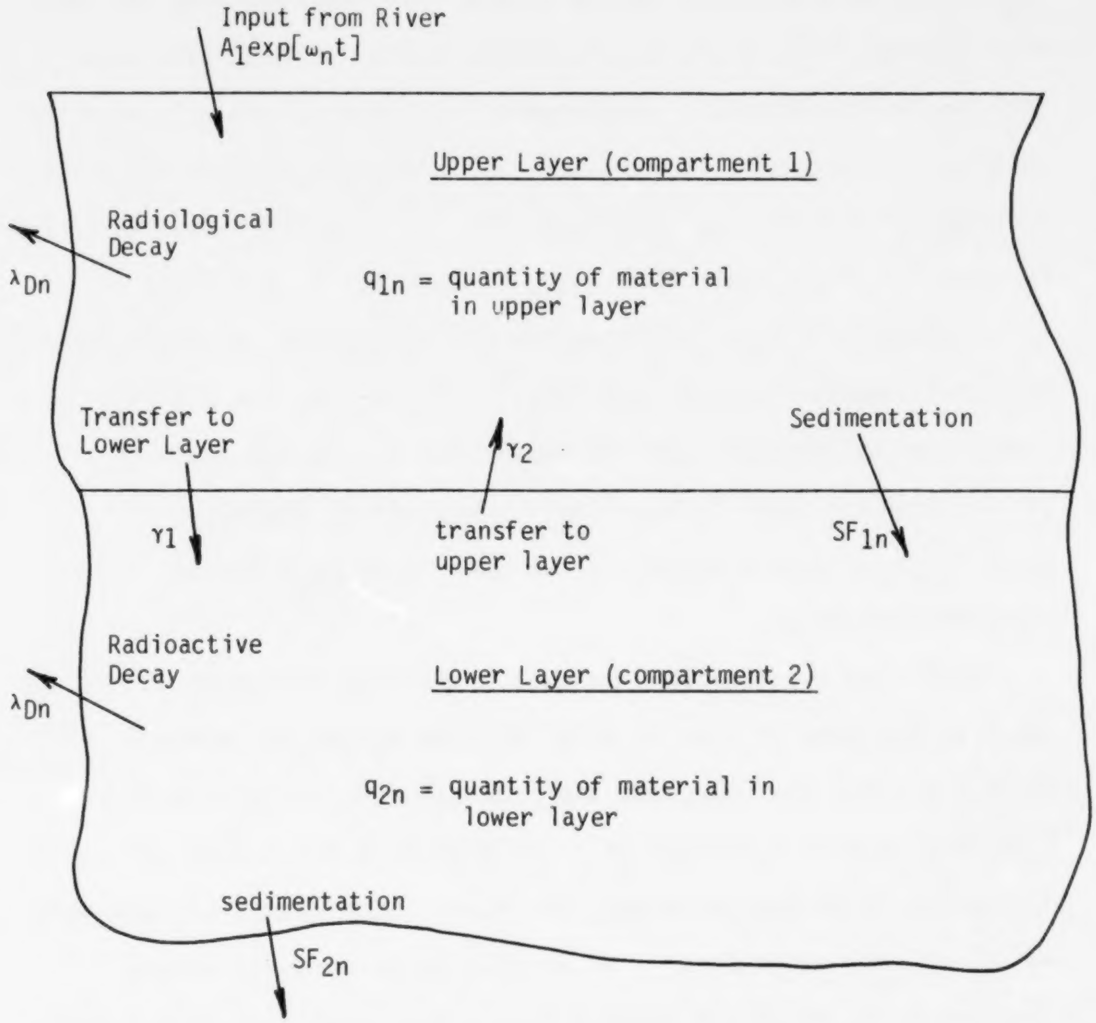
Input from River
$A_1\exp[\omega_n t]$
Upper Layer (compartment 1)
Radiological Decay
λ_{Dn}
q_{1n} = quantity of material in upper layer
Transfer to Lower Layer
γ_2
Sedimentation
γ_1
transfer to upper layer
SF_{1n}
Radioactive Decay
λ_{Dn}
Lower Layer (compartment 2)
q_{2n} = quantity of material in lower layer
sedimentation
SF_{2n}

Fig. 3.2.1-1. Compartment model for the ocean release mode

The steps involved in computing the environmental dose equivalent commitment from each nuclide to an organ are outlined below:

(a) Calculate the quantity of radionuclide n in the upper (mixed) layer of the ocean, q_{1n}, as a function of time, and the concentration in ocean water as a function of time.

(b) Calculate the concentration of radionuclide n in the edible fish and shellfish in the upper layer as a function of time.

(c) Apply the appropriate ingestion rates by the population for fish and shellfish to obtain the total ingestion radionuclide intake rate.

(d) Apply the appropriate ingestion dose commitment factors to determine the dose commitment rate by organ to the population from fish and shellfish consumption.

(e) Integrate the population dose commitment rate from time of arrival of radionuclides in the ocean to the desired time, t, to get the environmental dose-equivalent commitment.

3.2.2 Ocean Two-Compartment Model

To calculate the concentration of radionuclide n in the upper compartment, the quantity of n in the upper compartment, q_{1n}, must be predicted as a function of time and divided by the volume, V_1, of the upper compartment. To obtain q_{1n}, we must write a system of two coupled differential equations based on the nuclide balance in each compartment as depicted in Fig. 3.2.1-1. These equations are

$$\frac{dq_{1n}}{dt} = A_1 e^{\omega_n t} + \gamma_2 q_{2n} - (\lambda_{Dn} + \gamma_1 + SF_{1n}) q_{1n} \qquad (3.2.2\text{-}1)$$

and

$$\frac{dq_{2n}}{dt} = (SF_{1n} + \gamma_1)\, q_{1n} - (SF_{2n} + \lambda_{Dn} + \gamma_2)\, q_{2n} \qquad (3.2.2\text{-}2)$$

with the associated initial conditions of

$$q_{1n} = q_{2n} = 0 \quad \text{at} \quad t = t_{Rn}.$$

After transforming variables, these coupled differential equations may be solved by methods such as successive elimination to yield q_{1n} and q_{2n}. Since q_{2n}, the radioactivity in the lower compartment, is not used in the analysis for the ocean pathway, the analytical expression is not presented. Then

$$q_{1n} = \frac{A_{2n}}{(M_{2n} - M_{1n})} \left\{ \begin{array}{l} \dfrac{(a_{1n} - M_{2n})}{(\omega_n - M_{1n})}\, e^{M_{1n}(t-t_{Rn})} - \dfrac{(a_{1n} - M_{1n})}{(\omega_n - M_{2n})}\, e^{M_{2n}(t-t_{Rn})} \\ + \dfrac{(M_{2n} - M_{1n})\,(\omega_n - b_{2n})}{(\omega_n - M_{2n})\,(\omega_n - M_{1n})}\, e^{\omega_n(t-t_{Rn})} \end{array} \right\}$$

where (3.2.2-3)

$$A_{2n} = \lambda_{Ln}\, f_L\, Q_{on}\, e^{-\lambda_{Dn} t_{Rn}}$$

$$a_{1n} = -(\lambda_{Dn} + SF_{1n} + \gamma_1)$$

$$b_{2n} = -(\lambda_{Dn} + SF_{2n} + \gamma_2)$$

$$\omega_n = -(\lambda_{Dn} + \lambda_{Ln})$$

$$B_{3n} = -(a_{1n} + b_{2n})$$

$$C_{3n} = (a_{1n} \cdot b_{2n}) - [\gamma_1 \gamma_2 + \gamma_2 SF_{1n}]$$

$$M_{1n} = \frac{-B_{3n} + \sqrt{B_{3n}^2 - 4C_{3n}}}{2}$$

and

$$M_{2n} = \frac{-B_{3n} - \sqrt{B_{3n}^2 - 4C_{3n}}}{2} .$$

Equation 3.2.2-3 can be used to predict the quanity of a radionuclide, n, which is uniformly mixed within the upper compartment of the ocean at any time, t, after placement of radionuclides in a waste repository. If equation 3.2.2-3 is divided by V_1, an equation to express the average concentration of nuclide n in the upper compartment of the ocean is obtained.

3.2.3 Seafood Ingestion

Ocean Fish (p=9)
Ocean Shellfish (p=10)

The equation used to calculate EDC for these pathways is

$$S_{nop} = \frac{CF_{np} I_p P_p D_{nop}}{V_1} \int_{t_{Rn}}^{t} q_{1n} \, dt \qquad (3.2.3\text{-}1)$$

where q_{1n} is described in equation 3.2.2-3. Equation 3.2.3-1 is integrated between the limits of t_{Rn} and t since no dose is incurred prior to time $t=t_{Rn}$. After integration and normalization by the integrated source term (equation 2.1-4), the following expression for the EDC to an exposed population due to consumption of seafood is obtained:

$$\frac{S_{nop}}{Q_{np}} = \frac{D_{nop} CF_{np} I_p P_p}{V_1} \left[\frac{\lambda_{Dn} + \lambda_{Ln}}{1 - e^{-(\lambda_{Dn} + \lambda_{Ln})(t-t_{Rn})}} \right] (COM_n)$$

(3.2.3-2)

where

$$\mathrm{COM}_n = \left(\frac{1}{M_{2n} - M_{1n}}\right) \left\{ \frac{(a_{1n} - M_{2n})\left[\exp[M_{1n}\,(t-t_{Rn})] \quad -1\right]}{(\omega_n - M_{1n})\,(M_{1n})} - \frac{(a_{1n} - M_{1n})\left[\exp[M_{2n}\,(t-t_{Rn})] \quad -1\right]}{(\omega_n - M_{2n})\,(M_{2n})} + \frac{(M_{2n} - M_{1n})\,(\omega_n - b_{2n})\left[\exp[\omega_n(t-t_{Rn})] \quad -1\right]}{(\omega_n - M_{2n})\,(\omega_n - M_{1n})\,(\omega_n)} \right\}. \tag{3.2.3-3}$$

3.3 Releases to the Land Surface[*]

3.3.1 General Considerations

As discussed in Section 2, we assume that radioactive material is placed in a repository at time t=0 and that the material is brought to the surface of the earth at $t=t_L$ by some event such as exploratory drilling for resources. The release to the surface of the earth is assumed to be over a small area and over a short period of time so that the source to the land surface can be modeled as an instantaneous point source to the earth. This is conservative since some of the released material would probably be covered and less available than we have assumed. Once the initial source deposition to the land surface is determined, calculations can be made to estimate the resuspension of radioactive material at this source and to predict how this material disperses in the environment. The resuspended material results in exposure to the population due to consumption of contaminated food crops, inhalation of the resuspended material, and external exposure due to ground contamination and air submersion.

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[*] The variables used in the equations in this section are defined in the "Nomenclature" section, p. 102 ff.

3.3.2 Food Ingestion

Food crops ($p=13$)
Milk ($p=14$)
Beef ($p=15$)

We used the output from the AIRDOS-EPA computer code to compute the EDC due to food ingestion, which requires that the deposition to the ground surface be calculated so that the RI_{np} factors (see Section 3.1.4) can be applied. (Derivation of the equation for RI_{np} for food crops is discussed in detail in Appendix C.) In calculating air concentration as a function of distance and time, we assume Nelson's (Ne 78) isotropic dispersion, which was based on annual-average atmospheric dispersion factor data for ground-level releases at 17 nuclear power reactor sites as presented in Appendix I to 10 CFR 50 (AEC73). The equation is

$$X_{in}(r,t') = \left(\frac{X}{Q'}\right)_{r_n} Q'(t') \left(\frac{r}{r_n}\right)^{-z} \qquad (3.3.2\text{-}1)$$

where

$X_{in}(r,t')$ = air concentration at point r and time t' (Ci/m^3),

$(X/Q')_{r_n}$ = atmospheric dispersion factor at the known point r_n (sec/m^3),

$Q'(t')$ = source term from ground to air at time t' (Ci/yr)

z = "fitting" exponent to adjust shape of $X(r,t')$ curve to agree with empirical data, and

t' = time after material in repository reaches ground surface (yr).

An equation that describes $Q'(t')$ in terms of the material initially present at the ground surface is

$$Q'(t') = \lambda_R \, Q_{np} \exp\left[- (\lambda_R + \lambda_{Dn} + \lambda_{Sn}) \, t' \right] . \qquad (3.3.2\text{-}2)$$

But this equation is not corrected for plume depletion during travel. A correction factor which makes a downward adjustment of the source term, $Q'(t')$, to correct for plume depletion can be expressed as

$$\frac{Q_D'(t')}{Q'(t')} = \exp\left[-\left(\frac{r}{r_d}\right)^{(2-z)} \right] \qquad (3.3.2\text{-}3)$$

where

$$r_d = \left[\frac{(2-z) \, r_n^{-z}}{2\pi v_{gn} (X/Q')_{r_n}} \right]^{\frac{1}{2-z}} . \qquad (3.3.2\text{-}4)$$

Combining equations 3.3.2-2 and 3.3.2-3, we have

$$Q_D'(t') = \lambda_R \, Q_{np} \exp[-(\lambda_R+\lambda_{Dn}+\lambda_{Sn})t'] \exp\left[-\left(\frac{r}{r_d}\right)^{(2-z)}\right] ; \qquad (3.3.2\text{-}5)$$

and the equation for air concentration at a point r and at time t' due to dispersion of material resuspended from the point source is (substituting $Q_D(t')$ for $Q'(t')$ in equation 3.3.2-1)

$$X_{in}(r,t') = \left(\frac{X}{Q'}\right)_{r_n} \left(\frac{r}{r_n}\right)^{-z} \lambda_R \, Q_{np} \exp\left[-(\lambda_R+\lambda_{Dn}+\lambda_{Sn})t' - \left(\frac{r}{r_d}\right)^{(2-z)}\right] . \qquad (3.3.2\text{-}6)$$

We next estimate the deposition to the ground surface at distances away from the resuspension point by multiplying equation 3.3.2-6 by the dry deposition velocity. An equation that expresses the total deposition to the ground surface over all area and to time t' is obtained from equation 3.3.2-6 as follows:

$$DEP(\infty,t') = \int_{r=0}^{\infty} \int_{\theta=0}^{2\pi} \int_{t'=0}^{t'} X_{in}(r,t')v_{gn}\, dt'\, (r d\theta dr) . \qquad (3.3.2\text{-}7)$$

Performing these integrations yields an expression for the total deposition to the ground surface to time t':

$$DEP(\infty,t') = DEP(t') = \frac{\lambda_R\, Q_{np}}{\lambda_R+\lambda_{Dn}+\lambda_{Sn}} \left[1 - \exp[-(\lambda_R+\lambda_{Dn}+\lambda_{Sn})t'] \right] . \qquad (3.3.2\text{-}8)$$

To obtain the EDC for any one of the food pathways, we use a method similar to that described in section 3.1.4. The equation is

$$S_{nop} = \left[\frac{DEP(t')}{A_r}\right] f_p\, RI_{np}\, (CP_p\, A_r)\, D_{nop} \qquad (3.3.2\text{-}9)$$

where A_r is land area on which resuspended material is deposited, and the other terms have been previously defined or are listed in the "Nomenclature" section.

Upon cancelling the area terms, substituting equation 3.3.2-8 for DEP(t'), normalizing by the quantity of radionuclides initially released to the ground surface, Q_{np}, and redefining $t'=t-t_L$, equation 3.3.2-9 becomes

$$\frac{S_{nop}}{Q_{np}} = \frac{f_p \; RI_{np} \; CP_p \; D_{nop} \; \lambda_R \left[1- \; e^{-(\lambda_R + \lambda_{Dn} + \lambda_{Sn})(t - t_L)}\right]}{\lambda_R + \lambda_{Dn} + \lambda_{Sn}} \; .$$

(3.3.2-10)

3.3.3 Inhalation of Resuspended Material (p=12)

The calculation of the EDC due to inhalation of radioactive nuclides for the land surface pathway must consider the initial resuspension at the point source. In addition, deposition to the ground surface and resuspension from the ground surface away from the source must be modeled. An activity (mass) balance around a segment of ground away from the source can be depicted as shown in Fig. 3.3.3-1.

The soil surface concentration as a function of time and location is estimated so that a resuspension factor can be applied to obtain the air concentration as a function of time and location.

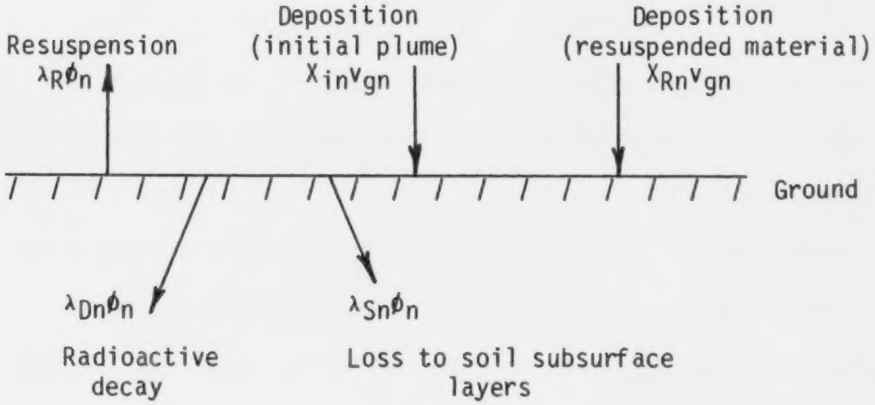
Resuspension
$\lambda_R \phi_n$
Deposition (initial plume)
$\chi_{in} v_{gn}$
Deposition (resuspended material)
$\chi_{Rn} v_{gn}$
Ground
$\lambda_{Dn} \phi_n$
Radioactive decay
$\lambda_{Sn} \phi_n$
Loss to soil subsurface layers

Fig. 3.3.3-1. Activity (mass) balance for soil element away from source

A differential equation which addresses the activity balance depicted in Fig. 3.3.3-1 is

$$\frac{d\phi_n}{dt'} = X_{in}v_{gn} + X_{Rn}v_{gn} - \lambda_R\phi_n - \lambda_{Dn}\phi_n - \lambda_{Sn}\phi_n \qquad (3.3.3\text{-}1)$$

where X_{in} is the air concentration of radionuclide n due to resuspension from the initial point source and subsequent dispersion and X_{Rn} is the air concentration of radionuclide n due to resuspension from the ground surface at the location of interest. The other terms have been previously defined. If the assumption is made that there is no redistribution of radioactive material due to continual deposition to and resuspension from the ground surface after equilibrium is reached, we may equate the terms $X_{Rn}v_{gn}$ and $\lambda_R\phi_n$ in equation 3.3.3-1 and write

$$\frac{dQ_n}{dt'} = X_{in}\,v_{gn} - (\lambda_{Dn} + \lambda_{Sn})\,\phi_n\,. \qquad (3.3.3\text{-}2)$$

An expression for X_{in} was discussed in Section 3.3.2 (equation 3.3.2-6). If this expression for X_{in} is applied in equation 3.3.3-2 and the integration factor $\exp(\lambda_{Dn}+\lambda_{Sn})t'$ is used, the equation is solved to yield an expression for the total soil surface concentration as a function of distance and time:

$$\phi_n(r,t') = v_{gn}\cdot Q_{np}\cdot\left(\frac{X}{Q'}\right)_{r_n}\cdot\left(\frac{r}{r_n}\right)^{-z}\cdot e^{-(r/r_d)^{(2-z)}}\cdot\left[e^{-(\lambda_{Dn}+\lambda_{Sn})t'} - e^{-(\lambda_R+\lambda_{Dn}+\lambda_{Sn})t'}\right].$$

(3.3.3-3)

Assuming, as discussed in Section 3.1.5, that the air concentration due to resuspension can be calculated by applying a resuspension factor to the soil surface concentration, we have

$$\chi_{Rn} = RF\ \phi_n(r,t') \quad . \qquad (3.3.3\text{-}4)$$

Then the total air concentration at a particular location and time is

$$\chi_n(r,t') = \chi_{in}(r,t') + \chi_{Rn}(r,t') \qquad (3.3.3\text{-}5)$$

and using equations 3.3.2-6, 3.3.3-3, and 3.3.3-4 we have

$$\chi_n(r,t') = Q_{np}\left(\frac{\chi}{Q'}\right)_{r_n}\left(\frac{r}{r_n}\right)^{-z} e^{[-(r/r_d)^{(2-z)}-\lambda_{Tn}t']}\left[\lambda_R + RF\cdot v_{gn}(e^{\lambda_R t'} -1)\right]$$

where $\lambda_{Tn} = \lambda_R + \lambda_{Dn} + \lambda_{Sn}$. (3.3.3-6)

Equation 3.3.3-6 yields an expression for air concentration to use in computing the EDC due to inhalation of resuspended material. The relationship to apply for calculating EDC is

$$S_{nop} = \int_0^{t'} \int_0^{A} \chi_n(r,t')\ I_B\ D_{nop}\ PD_p\ dA_r\ dt \quad . \qquad (3.3.3\text{-}7)$$

This equation is similar to the one derived for the inhalation pathway in Section 3.1.5. Using the expression for $\chi_n(r,t')$ from equation 3.3.3-6, the relationship $dA_r = rd\theta dr$, performing the area integration from $r=0$ to $r=\infty$ and $\theta=0$ to $\theta=2\pi$ (integrating over all area where people are exposed), and normalizing the result by the quantity of radionuclides released to the ground surface, Q_{np}, we have

$$\frac{S_{nop}}{Q_{np}} = \frac{PD_p \lambda_R I_B D_{nop}}{v_{gn}(\lambda_{Dn} + \lambda_{Sn})} [1 - e^{-(\lambda_{Dn} + \lambda_{Sn})t'}] \qquad (3.3.3\text{-}8)$$

Redefining t' as $t-t_L$ and using the relationship $RF = \lambda_R/v_{gn}$, the equation for EDC can be written

$$\frac{S_{nop}}{Q_{np}} = PD_p \; RF \; I_B \; D_{nop} \left[\frac{1 - e^{-(\lambda_{Dn} + \lambda_{Sn})(t-t_L)}}{\lambda_{Dn} + \lambda_{Sn}} \right] . \qquad (3.3.3\text{-}9)$$

3.3.4 External Dose-Ground Contamination (p=16)

The equation to apply in calculating EDC is

$$S_{nop} = \int_0^{t'} \int_0^{A} \phi_n(r,t') \; D_{nop} \; SOF \; PD_p \; dA \; dt \quad . \qquad (3.3.4\text{-}1)$$

Using the expression for $\phi_n(r,t')$ developed in Section 3.3.3 (equation 3.3.3-3), the relationship $dA_r = r d\theta dr$ with the integration limits $0 \leq r \leq$ and $0 \leq \theta \leq 2\pi$, normalizing the result by the initial release to the ground surface, Q_{np}, and redefining t' as $t-t_L$, equation 3.3.4-1 becomes

$$\frac{S_{nop}}{Q_{np}} = PD_p \; D_{nop} \; SOF \left[\frac{1 - e^{-(\lambda_{Dn} + \lambda_{Sn})(t-t_L)}}{\lambda_{Dn} + \lambda_{Sn}} + \frac{e^{-\lambda_{Tn}(t-t_L)} - 1}{\lambda_{Tn}} \right] \qquad (3.3.4\text{-}2)$$

where λ_{Tn} was defined in Section 3.3.3.

3.3.5 External Dose-Air Submersion (p=11)

The equation for calculating EDC is

$$S_{nop} = \int_0^{t'} \int_0^{A} X_n(r,t')\, D_{nop}\, SOF\, PD_p\, dA\, dt' . \qquad (3.3.5\text{-}1)$$

Using the expression for $X_n(r,t')$ developed in Section 3.3.3 (equation 3.3.3-6), the relationship $dA = r d\theta dr$ with the integration limits $0 \leq r \leq$ and $0 \leq \theta \leq 2\pi$, normalizing the result by the source term Q_{np}, and redefining t' as $t - t_L$, equation 3.3.5-1 becomes

$$\frac{S_{nop}}{Q_{np}} = PD_p\, D_{nop}\, SOF\, RF \left[\frac{1 - e^{-(\lambda_{Dn} + \lambda_{Sn})(t-t_L)}}{\lambda_{Dn} + \lambda_{Sn}} \right] \qquad (3.3.5\text{-}2)$$

3.4 Releases Due to Volcano/Meteorite Interaction*

3.4.1 General Considerations

We assume that either a volcano or a meteorite interacts with a waste repository and distributes material to the air and directly to the land surface in a small area around the volcano or meteorite. Because the interactions are violent, we assume that the material would be distributed uniformly throughout the troposphere. Radionuclides released to air will affect people differently depending on whether the nuclides are in the inhalation zone over land or in the air over the ocean and on whether they deposit on land or in the ocean. We account for this by splitting the inventory released into that over land and that over oceans using the respective surface areas of the oceans and the land surface of the earth. This division of the airborne material is for calculational convenience in developing the mathematical equations for the environmental dose commitment analyses. Each curie of radionuclide which is released is divided between that quantity released directly to the land surface (f_{LL}), that released to air above land (f_{AL}) and that released to air above oceans (f_{AW}). We assume that airborne material above land remains over land and that airborne material above water remains over water.

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*The variables used in the equations in this section are defined in the nomenclature, p. 102 ff.

3.4.2 Releases Directly to Land Surface

3.4.2.1 General Considerations

The radionuclides released directly to the land surface are conservatively assumed to be distributed in a small area around the release point. The methods used to determine the resuspension at the source, dispersion in the environment, and resulting EDC to the affected population are the same as those devised for the land surface pathway (Section 3.3). The equations used for releases directly to the land surface will be listed, for the sake of completeness, in the following sections.

3.4.2.2 Food Ingestion

Food Crops (p=25)
Milk (p=26)
Beef (p=27)

$$\frac{S_{nop}}{Q_{np}} = f_p \, RI_{np} \, CP_p \, D_{nop} \, f_{LL} \, \lambda_R \, \frac{[1 - e^{-\lambda_{Tn}(t-t_v)}]}{\lambda_{Tn}} \qquad (3.4.2.2\text{-}1)$$

where f_{LL} is the fraction of the radionuclides released to the environment which go directly to land and t_v is the time after placement of radioactive material in the repository that material is released to the environment.

3.4.2.3 Inhalation of Resuspended Material (p=24)

$$\frac{S_{nop}}{Q_{np}} = PD_p \; RF \; I_B \; D_{nop} \; f_{LL} \left[\frac{1 - e^{-(\lambda_{Dn} + \lambda_{Sn})(t-t_v)}}{\lambda_{Dn} + \lambda_{Sn}} \right]. \qquad (3.4.2.3\text{-}1)$$

3.4.2.4 External Dose - Ground Contamination (p=28)

$$\frac{S_{nop}}{Q_{np}} = PD_p \; D_{nop} \; SOF \; f_{LL} \left[\frac{1 - e^{-(\lambda_{Dn} + \lambda_{Sn})(t-t_v)}}{\lambda_{Dn} + \lambda_{Sn}} + \frac{e^{-\lambda_{Tn}(t-t_v)} - 1}{\lambda_{Tn}} \right].$$

(3.4.2.4-1)

3.4.2.5 External Dose - Air Submersion (p=23)

$$\frac{S_{nop}}{Q_{np}} = PD_p \; D_{nop} \; RF \; SOF \; f_{LL} \left[\frac{1 - e^{-(\lambda_{Dn} + \lambda_{Sn})(t-t_v)}}{\lambda_{Dn} + \lambda_{Sn}} \right].$$

(3.4.2.5-1)

3.4.3 Releases to Air-Over-Land

3.4.3.1 General Considerations

The radionuclides released to the air over land surfaces are assumed to be distributed uniformly in a volume determined by multiplying the land surface area of the earth by the average height of the troposphere. With the material distributed in this manner a two compartment model is established, as depicted in Fig. 3.4.3.1-1, to predict radionuclide movement between the air and the soil for use in computing the EDC for the various pathways. The upper compartment in Fig. 3.4.3.1-1 is the tropospheric volume above the earth's land surface and the lower compartment is the available land layer, i.e., the layer of land containing the soil surface as an upper boundary and including the root zone or plow layer of soil. It is assumed that radionuclides enter the upper compartment at the instant a volcano or meteorite interaction releases radioactivity from the repository. No further radionuclides are introduced into the system after the initial input at $t' = 0$.

Radionuclides leave the upper compartment by radioactive decay (λ_{Dn}) and by transfer from air to soil ($v_{gn} \cdot A_L / V_L$) and they reenter the upper compartment due to resuspension (λ_R). Radionuclides enter the lower compartment by deposition from air ($v_{gn} \cdot A_L / V_L$) and are removed from the lower compartment by transfer to the unavailable soil layer (λ_{Sn}), radioactive decay (λ_{Dn}), and resuspension from the soil layer to air (λ_R). The radionuclide balance equations which can be written for this two compartment system are discussed in the next section.

3.4.3.2 Air-Above-Land: Two Compartment Model

To obtain the concentration of radionuclide n in the upper (air) compartment, the quantity of n in the upper compartment, $Q_{Ln}(t')$, must be predicted as a function of time and divided by the volume, V_L, of the upper air compartment. Similarly, to obtain the concentration of radionuclide n on the ground surface represented by the lower compartment,

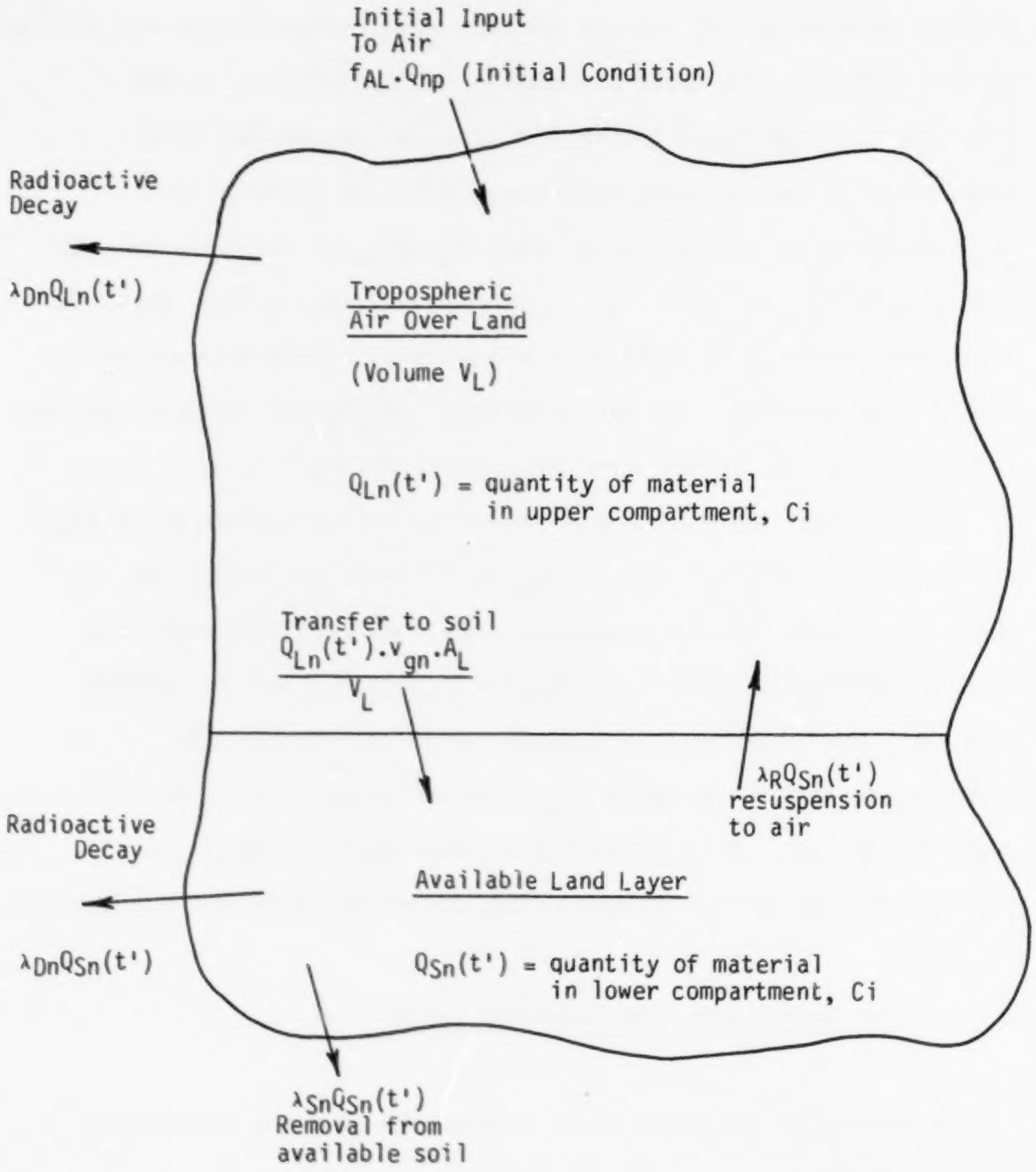
Initial Input
To Air
$f_{AL} \cdot Q_{np}$ (Initial Condition)
Radioactive Decay
$\lambda_{Dn} Q_{Ln}(t')$
Tropospheric Air Over Land
(Volume V_L)
$Q_{Ln}(t')$ = quantity of material in upper compartment, Ci
Transfer to soil
$\frac{Q_{Ln}(t') \cdot v_{gn} \cdot A_L}{V_L}$
$\lambda_R Q_{Sn}(t')$
resuspension to air
Radioactive Decay
$\lambda_{Dn} Q_{Sn}(t')$
Available Land Layer
$Q_{Sn}(t')$ = quantity of material in lower compartment, Ci
$\lambda_{Sn} Q_{Sn}(t')$
Removal from available soil

Fig. 3.4.3.1-1. Compartment model for air over land -- volcano/meteorite release mode

the quantity of n in the lower compartment, $Q_{Sn}(t')$ must be predicted as a function of time and divided by the surface area, A_L, for the lower compartment. To obtain $Q_{Ln}(t')$ and $Q_{Sn}(t')$, a system of two coupled differential equations based on the nuclide balance shown in Fig. 3.4.3.1-1 is written and solved. These equations are:

$$\frac{dQ_{Ln}}{dt} = - \lambda_{Dn} Q_{Ln} - \frac{v_{gn} A_L}{V_L} Q_{Ln} + \lambda_R Q_{Sn} \qquad (3.4.3.2\text{-}1)$$

and

$$\frac{dQ_{Sn}}{dt} = \frac{v_{gn} A_L}{V_L} Q_{Ln} - \lambda_{Dn} Q_{Sn} - \lambda_{Sn} Q_{Sn} - \lambda_R Q_{Sn} , \qquad (3.4.3.2\text{-}2)$$

and the initial conditions for our model are

$$Q_{Ln}(0) = f_{AL} Q_{np}$$

and

$$Q_{Sn}(0) = 0 \qquad \text{at } t' = 0 .$$

After a transformation of variables, these coupled differential equations may be solved to yield Q_{Ln} and Q_{Sn} as follows:

$$Q_{Ln}(t') = \frac{f_{AL} \cdot Q_{np}}{M_{6n} - M_{5n}} \left[(M_{6n} - a_{5n}) e^{M_{5n}t'} + (a_{5n} - M_{5n}) e^{M_{6n}t'} \right] \qquad (3.4.3.2\text{-}3)$$

$$Q_{Sn}(t') = -\frac{f_{AL} Q_{np} (M_{5n} - a_{5n})(M_{6n} - a_{5n})}{\lambda_R (M_{6n} - M_{5n})} \left[e^{M_{5n}t'} - e^{M_{6n}t'} \right] \qquad (3.4.3.2\text{-}4)$$

where

$$a_{5n} = - (\lambda_{Dn} + \frac{v_{gn}}{h_a})$$

$$b_{6n} = - (\lambda_{Dn} + \lambda_{Sn} + \lambda_R)$$

$$B_{4n} = - (a_{5n} + b_{6n})$$

$$C_{4n} = a_{5n}\, b_{6n} - \frac{v_{gn}}{h_a} \lambda_R$$

$$M_{5n} = - \frac{B_{4n} + \sqrt{B_{4n}^2 - 4C_{4n}}}{2}$$

$$M_{6n} = - \frac{B_{4n} - \sqrt{B_{4n}^2 - 4C_{4n}}}{2} .$$

Now, using equations 3.4.3.2-3 and 3.4.3.2-4, the air and ground concentrations of radionuclides as a function of time can be calculated.

To compute the air concentration in the upper compartment as a function of time, equation 3.4.3.2-3 is divided by the volume of the upper compartment, which is $V_L = A_L . h_A$, to yield

$$X_n(t') = \frac{f_{AL} \,.\, Q_{np}}{A_L \cdot h_A\, (M_{6n} - M_{5n})} \left[(M_{6n} - a_{5n})\, e^{M_{5n}t'} + (a_{5n} - M_{5n})\, e^{M_{6n}t'} \right] . \qquad (3.4.3.2\text{-}5)$$

The ground concentration for the lower compartment as a function of time is obtained by dividing equation 3.4.3.2-4 by the surface area, A_L, of the lower compartment to yield

$$\phi_n(t') = \frac{f_{AL} \cdot Q_{np} (M_{5n} - a_{5n})(M_{6n} - a_{5n})}{\lambda_R (M_{6n} - M_{5n})\, A_L} \left[e^{M_{5n}t'} - e^{M_{6n}t'} \right] \qquad (3.4.3.2\text{-}6)$$

The equations generated above are used for the EDC pathway models discussed below.

3.4.3.3. Food Ingestion

Food crops (p=19)
Milk (p=20)
Beef (p=21)

The output of the AIRDOS-EPA computer code (Mo79) will again be employed in computing the EDC due to food ingestion. The method for deriving the equation for RI_{np} for food crops is discussed in detail in Appendix C. The deposition to the ground surface due to the radioactive material originally distributed in the air above the land surface (neglecting resuspension) is calculated and applied in conjunction with the values of RI_{np} computed using AIRDOS-EPA. Since the factors were determined without considering resuspension, we must compute the radionuclide flux to ground as a function of time for the radionuclides originally dispersed into the air at $t'=0$. Referring to Fig. 3.4.3.1-1, the flux of nuclide n to ground as a function of time, $F'_n(t')$, can be calculated as

$$F'_n(t') = \frac{Q_{Ln}(t') \cdot v_{gn}}{V_L} \qquad (3.4.3.3\text{-}1)$$

where, for these three subpathways, $Q_{Ln}(t')$ is determined using equation 3.4.3.2-3 with λ_R set equal to 0. Setting $\lambda_R=0$ will yield $Q_{Ln}(t')$ based only on material originally dispersed in the air and neglects resuspension altogether. To obtain $F_n(t')$, the quantity of radionuclide n deposited per unit area from the time material was originally dispersed into the air ($t'=0$) to time t', we integrate as follows:

$$F_n(t') = \int_0^{t'} F'_n(t')\,dt' = \int_0^{t'} \frac{f_{AL} \cdot Q_{np}}{(M_{6n} - M_{5n})} \left[(M_{6n} - a_{5n})\, e^{M_{5n} t'} + (a_{5n} - M_{5n})\, e^{M_{6n} t'} \right] \frac{v_{gn}}{V_L}\, dt' .$$

(3.4.3.3-2)

After integrating, the result is

$$F_n(t') = \frac{f_{AL} \cdot Q_{np} \cdot v_{gn}}{(M_{6n} - M_{5n}) \cdot V_L} \left[\frac{(M_{6n} - a_{5n})}{M_{5n}} \left(e^{M_{5n} t'} - 1 \right) + \frac{(a_{5n} - M_{5n})}{M_{6n}} \left(e^{M_{6n} t'} - 1 \right) \right]$$

(3.4.3.3-3)

which has units of Ci deposited per m^2. The EDC for these pathways is derived in a manner similar to the methods applied in Section 3.1.4 and may be computed using the following equation:

$$S_{nop} = F_n(t') \quad f_p \quad RI_{np} \quad D_{nop} \quad CP_p \quad A_L \quad .$$

(3.4.3.3-4)

After substituting equation 3.4.3.3-3 for $F_n(t')$, normalizing by the original total release Q_{np}, substituting $V_L = A_L . h_A$, and making the substitution $t' = t - t_v$, we have

$$\frac{S_{nop}}{Q_{np}} = \frac{f_{AL} \; v_{gn} \; D_{nop} \; RI_{np} \; f_p \; CP_p}{h_A} \left\{ \begin{array}{l} \dfrac{(M_{6n} - a_{5n})}{M_{5n}(M_{6n} - M_{5n})} \left[e^{M_{5n}(t - t_v)} - 1 \right] \\ + \dfrac{(a_{5n} - M_{5n})}{M_{6n}(M_{6n} - M_{5n})} \left[e^{M_{6n}(t - t_v)} - 1 \right] \end{array} \right\}$$

(3.4.3.3-5)

or, defining $COML_n$ as:

$$COML_n = \frac{(M_{6n} - a_{5n})}{M_{5n}(M_{6n} - M_{5n})} \left[e^{M_{5n}(t - t_v)} - 1 \right] + \frac{(a_{5n} - M_{5n})}{M_{6n}(M_{6n} - M_{5n})} \left[e^{M_{6n}(t - t_v)} - 1 \right]$$

(3.4.3.3-6)

$$\frac{S_{nop}}{Q_{np}} = \frac{f_{AL} \; v_{gn} \; D_{nop} \; RI_{np} \; f_p \; CP_p \; COML_n}{h_A} \quad .$$

(3.4.3.3-7)

Again, it is important to note that, for these three pathways ($p=19, 20, 21$), $COML_n$ is evaluated with $\lambda_R = 0$.

3.4.3.4 Inhalation of Dispersed and Resuspended Material (p=17)

In considering the EDC due to inhalation of dispersed and resuspended material an equation similar to the one derived in Section 3.1.5 was used, which is

$$S_{nop} = \left[\int_{t'=0}^{t'=t'} X_n(t')\, dt' \right] I_B\, D_{nop}\, PD_p\, A_L \quad . \qquad (3.4.3.4\text{-}1)$$

Since the equation for $X_n(t')$ has already been described in equation 3.4.3.2-5, it can be substituted into equation 3.4.3.4-1. After performing the indicated integration, normalizing by the release of radionuclide n at t'=0 and replacing t' by $t-t_v$, we have

$$\frac{S_{nop}}{Q_{np}} = \frac{f_{AL}\, I_B\, D_{nop}\, PD_p}{h_A}\, COML_n \quad . \qquad (3.4.3.4\text{-}2)$$

3.4.3.5 External Dose-Ground Contamination (p=22)

The equation to use in deriving an expression for the EDC for contaminated ground is

$$S_{nop} = \left[\int_{t'=0}^{t'=t'} \phi_n(t')\, dt \right] D_{nop}\, PD_p\, A_L \quad . \qquad (3.4.3.5\text{-}1)$$

Equation 3.4.3.2-6 is used to express $\phi_n(t')$. After the equation for S_{nop} is integrated and normalized by the initial release from the repository, Q_{np}, and t' is redefined as $t-t_v$, the EDC equation becomes

$$\frac{S_{nop}}{Q_{np}} = f_{AL}\ D_{nop}\ SOF\ PD_p\ \frac{(M_{5n}-a_{5n})(M_{6n}-a_{5n})}{\lambda_R(M_{6n}-M_{5n})} \left[\frac{[e^{M_{5n}\ (t-t_v)}-1]}{M_{5n}} - \frac{[e^{M_{6n}(t-t_v)}-1]}{M_{6n}} \right] . \qquad (3.4.3.5\text{-}2)$$

3.4.3.6 External Dose-Air Submersion (p=18)

For air submersion external doses, the EDC equation is written as

$$S_{nop} = \left[\int_{t'=0}^{t'=t'} X_n(t')\ dt \right] D_{nop}\ PD_p\ A_L \quad . \qquad (3.4.3.6\text{-}1)$$

Equation 3.4.3.2-5 can be substituted for $X_n(t')$. After the equation for S_{nop} is integrated and normalized by the initial release from the repository, Q_{np}, and t' is redefined as $t-t_v$, the EDC equation becomes

$$\frac{S_{nop}}{Q_{np}} = \frac{f_{AL}\ D_{nop}\ PD_p\ COML_n}{h_A} \quad . \qquad (3.4.3.6\text{-}2)$$

3.4.4 Releases to Air-Over-Oceans

3.4.4.1 General Considerations

The radionuclides released to the air over the oceans are assumed to be distributed uniformly in a volume determined by multiplying the earth's ocean area by the average height of the troposphere. With the material distributed in this manner a three compartment model is established, as shown in Fig. 3.4.4.1-1, to describe radionuclide movement between the air and the two ocean compartments. Using this model, concentrations of radionuclides can be determined as a function of time in the air and in each of the two ocean compartments. These concentrations can be used in estimating the EDC for the pathways considered in this section.

The upper compartment (Compartment 1) in Fig. 3.4.4.1-1 is the tropospheric volume above the earth's oceans. The middle compartment (Compartment 2) is the top compartment of the ocean and the lower compartment (Compartment 3) is the bottom compartment of the ocean.

We assume that radionuclides enter the air (Compartment 1) at the instant a volcano or meteorite interaction releases radioactivity from the repository and that no additional radioactivity is injected into the system after that. Radionuclides leave the air compartment by radioactive decay (λ_{Dn}) and by deposition into the ocean ($v_{gn}A_W/V_{AW}$). Radionuclides enter Compartment 2 by deposition from the air ($v_{gn}A_W/V_{AW}$) and by transfer from Compartment 3 (γ_2). Radionuclides leave Compartment 2 by radioactive decay (λ_{Dn}) and by diffusion transfer (γ_1) and sedimentation transfer (SF_{1n}) to Compartment 3. Radionuclides enter Compartment 3 by diffusion transfer (γ) and sedimentation transfer (SF_{1n}) from the upper ocean compartment and leave this compartment by radioactive decay (λ_{Dn}), sedimentation to the ocean floor (SF_{2n}), and transfer to the upper ocean compartment (γ_2). The differential equations which can be solved for radionuclide inventory in this three compartment system are discussed in the next section.

3.4.4.2 Air-Above Water: Three Compartment Model

The EDC pathways considered for air-over-oceans are consumption of ocean fish and shellfish. Since the assumption is made that all edible fish and

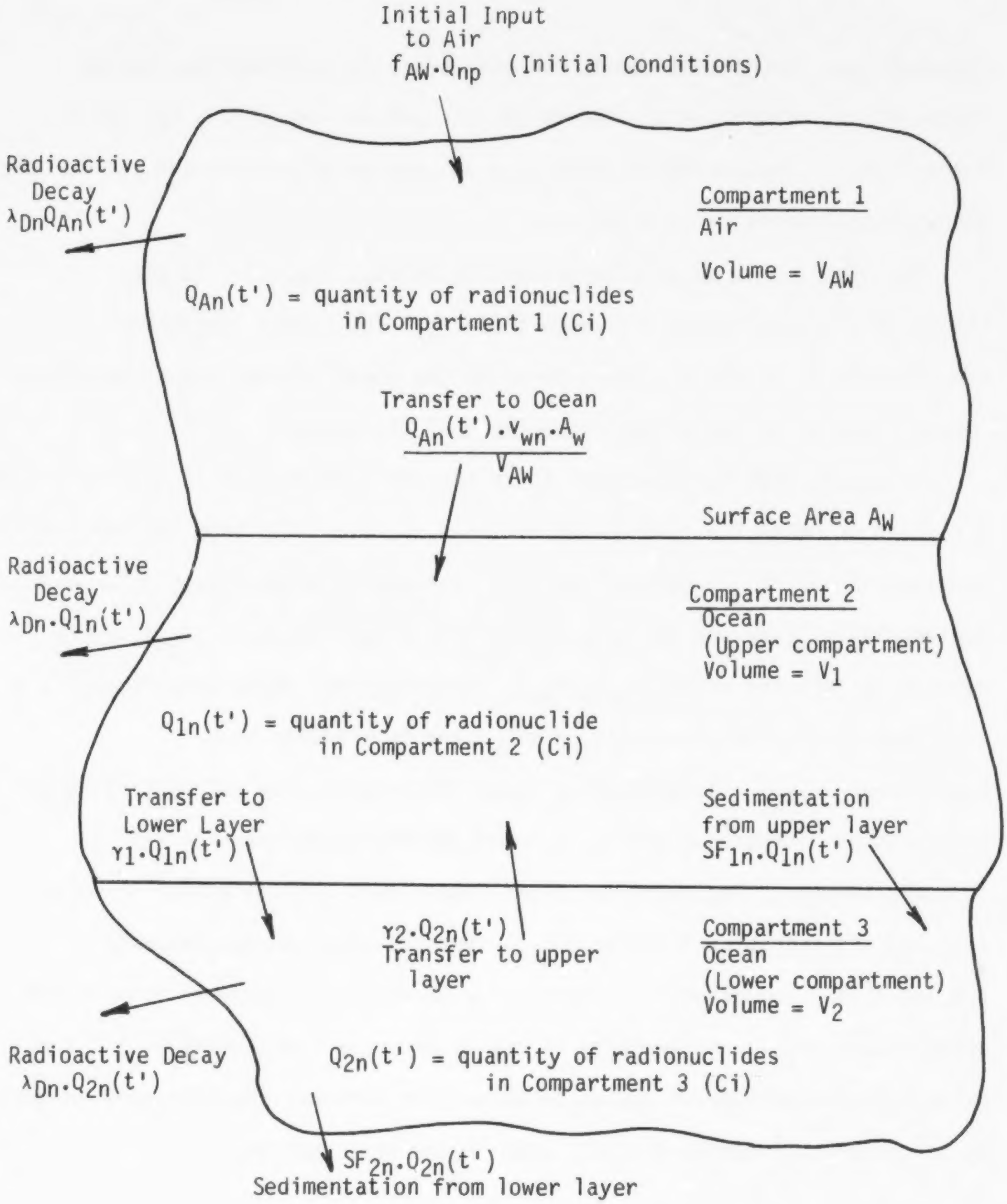
Initial Input to Air
$f_{AW} \cdot Q_{np}$ (Initial Conditions)
Radioactive Decay
$\lambda_{Dn} Q_{An}(t')$
Compartment 1
Air
Volume = V_{AW}
$Q_{An}(t')$ = quantity of radionuclides in Compartment 1 (Ci)
Transfer to Ocean
$\frac{Q_{An}(t') . v_{wn} . A_w}{V_{AW}}$
Surface Area A_W
Radioactive Decay
$\lambda_{Dn} \cdot Q_{1n}(t')$
Compartment 2
Ocean
(Upper compartment)
Volume = V_1
$Q_{1n}(t')$ = quantity of radionuclide in Compartment 2 (Ci)
Transfer to Lower Layer
$\gamma_1 \cdot Q_{1n}(t')$
Sedimentation from upper layer
$SF_{1n} \cdot Q_{1n}(t')$
$\gamma_2 \cdot Q_{2n}(t')$
Transfer to upper layer
Compartment 3
Ocean
(Lower compartment)
Volume = V_2
Radioactive Decay
$\lambda_{Dn} \cdot Q_{2n}(t')$
$Q_{2n}(t')$ = quantity of radionuclides in Compartment 3 (Ci)
$SF_{2n} \cdot Q_{2n}(t')$
Sedimentation from lower layer

Fig. 3.4.4.1-1. Compartment model for air-over-ocean, volcano/meteorite release mode

shellfish are harvested in the upper ocean layer, it will be necessary to obtain the quantity of each nuclide, $Q_{1n}(t')$, in the middle compartment (upper ocean layer). This quantity can be divided by the volume of the middle compartment, V_1, to yield the concentration in the zone where edible fish and shellfish are produced. The differential equations which describe the transfer of radionuclides between compartments in Fig. 3.4.4.1-1 and which are used to obtain the quantitites of radionuclides in the three compartments are

$$\frac{dQ_{An}}{dt'} = -(\lambda_{Dn} + \frac{v_{wn} A_w}{V_{AW}}) Q_{An} \qquad (3.4.4.2\text{-}1)$$

$$\frac{dQ_{1n}}{dt'} = \gamma_2 Q_{2n} + \frac{v_{wn} A_w}{V_{AW}} Q_{An} - (SF_{1n} + \lambda_{Dn} + \gamma_1) Q_{1n} \qquad (3.4.4.2\text{-}2)$$

and

$$\frac{dQ_{2n}}{dt'} = (\gamma_1 + SF_{1n}) Q_{1n} - (\lambda_{Dn} + SF_{2n} + \gamma_2) Q_{2n} \quad . \qquad (3.4.4.2\text{-}3)$$

The initial conditions for this model are

$$Q_{An} = f_{AW} Q_{np}$$

and

$$Q_{1n} = Q_{2n} = 0 \qquad \text{at } t'' = 0 \quad .$$

The procedure used to solve these differential equations is to integrate equation 3.4.4.2-1 directly and then use the resulting equation for Q_{An} in the solution of equations 3.4.4.2-2 and 3.4.4.2-3, which are coupled differential equations. The resulting equations for Q_{An} and Q_{1n} are

$$Q_{An}(t') = f_{AW} Q_{np} e^{-(\lambda_{Dn} + \lambda_{wn}) t'} \qquad (3.4.4.2\text{-}4)$$

$$Q_{1n}(t') = \frac{A_{2n}}{(M_{2n}-M_{1n})}\left[\frac{(a_{1n}-M_{2n})}{(\omega_n-M_{1n})}e^{M_{1n}t'} - \frac{(a_{1n}-M_{1n})}{(\omega_n-M_{2n})}e^{M_{2n}t'} + \frac{(M_{2n}-M_{1n})(\omega_n-b_{2n})}{(\omega_n-M_{2n})(\omega_n-M_{1n})}e^{\omega_n t'}\right] \tag{3.4.4.2-5}$$

where

$$A_{2n} = \frac{v_{wn}\ f_{AW}\ Q_{np}}{h_A}$$

$$\omega_n = -(\lambda_{Dn} + \lambda_{wn})$$

and a_{1n}, b_{2n}, B_{3n}, C_{3n}, M_{1n} and M_{2n} are as defined in Section 3.2.2. $Q_{2n}(t')$ is not needed in this analysis, so the equation for $Q_{2n}(t')$ is not presented.

The concentration of radionculides in the upper compartment of the ocean as a function of time can be computed by dividing equation 3.4.4.2-5 by V_1, the volume of the upper ocean compartment, which yields

$$X_{1n}(t') = \frac{A_{2n}}{(M_{2n}-M_{1n})V_1}\left[\frac{(a_{1n}-M_{2n})}{(\omega_n-M_{1n})}e^{M_{1n}t'} - \frac{(a_{1n}-M_{1n})}{(\omega_n-M_{2n})}e^{M_{2n}t'} + \frac{(M_{2n}-M_{1n})(\omega_n-b_{2n})}{(\omega_n-M_{2n})(\omega_n-M_{1n})}e^{\omega_n t'}\right] \tag{3.4.4.2-6}$$

3.4.4.3 Seafood Ingestion — Ocean Fish (p=29)
Ocean Shellfish (p=30)

The equation used to calculate EDC for these pathways is:

$$S_{nop} = \frac{CF_{np}\ I_p\ P_p\ D_{nop}}{V_1} \int_{t'=0}^{t'=t'} Q_{1n}\, dt' \tag{3.4.4.3-1}$$

where Q_{1n} is described by equation 3.4.4.2-5. After performing the integration, normalizing by the total release, Q_{np}, and making the substitution $t'=t-t_v$, we have

$$\frac{S_{nop}}{Q_{np}} = \frac{CF_{np}\ I_p\ P_p\ D_{nop}\ v_{wn}\ f_{AW}}{h_A\ V_1}\ COMO_n \qquad (3.4.4.3\text{-}2)$$

where

$$COMO_n = \frac{1}{M_{2n}-M_{1n}} \left\{ \frac{(a_{1n}-M_{2n})[\ e^{M_{1n}(t-t_v)}-1]}{(\omega_{sn}-M_{1n})M_{1n}} - \frac{(a_{1n}-M_{1n})[\ e^{M_{2n}(t-t_v)}-1]}{(\omega_{sn}-M_{2n})M_{2n}} + \frac{(M_{2n}-M_{1n})(\omega_{sn}-b_{2n})[\ e^{\omega_{sn}(t-t_v)}-1]}{(\omega_{sn}-M_{2n})(\omega_{sn}-M_{1n})\omega_{sn}} \right\}. \qquad (3.4.4.3\text{-}3)$$

3.5 Special Calculations for C-14 Environmental Dose Commitment

The pathway models described in Sections 3.1 through 3.4 are used for all pathway EDC calculations for all nuclides except carbon-14. Atmospheric releases of carbon-14 as carbon dioxide can be evaluated using a diffusion-type model of the carbon cycle developed by Killough (Ki77), but, to our knowledge, models are not available to explicitly treat C-14 released to the water or C-14 released to the air in a chemical form other than carbon dioxide. We used the Killough model in the evaluation of C-14 releases from the volcano/meteorite release mode since carbon is expected to be released as carbon dioxide. Since C-14 releases to a river, an ocean, or directly to a land surface are expected to be in a chemical form other than carbon dioxide, the standard pathway models described in Section 3 are also applied for C-14 releases except for the pathways involving ingestion of food crops, milk, or beef.

Special treatment was given C-14 in calculating the parameter RI_{np} because we believe that the terrestrial food chain model used in the calculation of this parameter for the other radionuclides would overestimate the calculated parameter for C-14. Transport processes within soil, plants, cattle, and man that apply to trace quantities of radionuclides do not necessarily apply to cases where the corresponding stable elements are present in such quantities that saturation effects are significant (Mo79). Stable carbon constitutes a significant fraction of the elemental composition of the human body and man's food and drink. We believe that the overestimate will still result if the terrestrial food chain model (NRC77) includes additional removal terms to account for removal of C-14 from the agricultural system by harvesting and removal of C-14 from the soil by leaching to the soil sink (e.g., removal of C-14 to soil beneath the root zone).

A specific activity model was used to provide a conservative estimate of the C-14 environmental dose commitment from ingestion of food crops for the river irrigation pathway:

$$\frac{S_{nop}}{Q_{np}} = \frac{f_{cp}\ f_p\ CP_p\ A\ I_c\ D_{nop}}{C_c\ R} \qquad (3.5\text{-}1)$$

where

f_{cp} = fraction of the standard man organ C-14 specific activity that is maintained by food intake pathway p

C_c = concentration of stable carbon in freshwater, (gm C/liter),

I_c = total dietary intake rate of carbon by standard man (gm C/yr),

A = irrigated area (m^2),

and the other terms are defined in the "Nomenclature" section.

The conservative assumption was made that the integrated specific activity of C-14 [Q_{np}/C_cR (Ci yr/gm C)] in the river water and in man are the same. The specific activity method is based on the assumption of instantaneous equilibrium, thereby providing an upper limit to the estimated dose equivalent rate. In equation 3.5-1, the parameter product I_cD_{nop} represents the specific activity dose equivalent rate conversion factor having units of rem/yr per Ci C-14/gm C. Therefore, values of D_{nop} must be obtained using a steady-state model of carbon specific activity in various organs of the body rather than a dynamic retention model for carbon. Our values of D_{nop} for carbon-14 were taken from dose conversion factors presented by Killough (Ki78). Equation 3.5-1 can be simplified by rewriting the ratio A/R as f_R/W where f_R is the fraction of the river flow used for irrigation and W is the irrigation rate (liters/m^2-yr):

$$\frac{S_{nop}}{Q_{np}} = \frac{f_{cp}\ f_p\ f_R\ CP_p\ I_c\ D_{nop}}{WC_c} \quad . \qquad (3.5\text{-}2)$$

The parameters in equation 3.5-2 can be used to calculate the integrated intake by standard man per unit deposition of C-14 to the soil surface (RI_{np} in Ci intake per Ci/m^2 deposited on the soil surface):

$$RI_{np} = \frac{I_c\ f_{cp}}{W\ C_c} \quad . \qquad (3.5\text{-}3)$$

Substituting the expression for RI_{np} into equation 3.5-2, the following equation can be used to calculate the environmental dose commitment from C-14 releases to the river due to ingestion of food crops, milk and beef (pathways 3, 4, and 5):

$$\frac{S_{nop}}{Q_{np}} = f_R \, f_p \, RI_{np} \, CP_p \, D_{nop} \, . \qquad (3.5\text{-}4)$$

Note that equation 3.5-4 is identical to equation 3.1.4-7 when WA is substituted for $f_R R$. A specific activity model was used to calculate the parameter RI_{np} for C-14; whereas, the AIRDOS-EPA computer code (Mo79) was used to calculate RI_{np} for the other evaluated radionuclides.

Values for the parameters used in calculations for carbon-14 are contained in the following discussion. Most of the parameters were used only for the C-14 calculations; however, a few were also used in calculations for other radionuclides. The values for parameters used for radionuclides other than C-14 are discussed in Section 5 of this report.

Adult man ingests 1.095 E+5 gm C/yr (I_c) in food and fluids, which is based on the ICRP recommended (ICRP75) dietary intake of 300 gm C/day. The fraction of the standard man organ specific activity (f_{cp}) maintained by each of the food intake pathways was calculated using Moore's (Mo79) equations for estimating carbon intakes for meat, milk, and vegetables. Ingestion rates needed to calculate carbon intakes were also taken from Moore (Mo79) as follows: 18 kg/yr of leafy vegetables; 176 kg/yr of other fresh produce; 94 kg/yr of meat (excluding fish); and 112 liters/yr of milk. Carbon weight fractions were calculated using the conservative assumption that the entire 300 gm C/day intake is from the food pathways. The resulting carbon food crop weight fractions (f_{cp}) were 0.3567 for food crops, 0.4659 for beef, and 0.177 for milk.

We selected a C_c value of 6 E-2 gm C/liter, which is consistent with carbon concentrations reported for public water supplies of 100 cities (CRC73). The concentration of stable carbon in freshwater (C_c)

ranges over several orders of magnitude. Wetzel and Rich (We73) stated that a typical range for inorganic carbon (the dominant chemical form in freshwater) is 50 micromoles to 10 millimoles per liter. The mean concentration for the range is 5 E-3 mole CO_2 per liter, and this corresponds with a concentration of stable carbon of 6 E-2 gm C/liter water, which was chosen for this analysis. The concentration of bicarbonate, HCO_3, in natural water is commonly less than 500 mg/liter, but it may exceed 1,000 mg/liter in water highly charged with carbon dioxide. The maximum reported concentration in the public water supplies of 100 cities was 380 mg HCO_3/liter (CRC73), which corresponds to a stable carbon concentration of 7.5 E-2 gm C/liter.

The irrigation rate (W) of 2 E+3 liters/m^2-yr was chosen based on the upper basin irrigation rate, or 0.23 liters/m^2-hr (Li77C). This irrigation rate was based on data typical of the Colorado River mainstream.

The fraction of the river flow used for irrigation (f_R) was set equal to 0.5. Fractions representative of irrigation water use by 17 western states were estimated to test the reasonableness of the assumption of f_R equal to 0.5. Using presented (CRC73) rates of use for irrigation water in 1970 and river flow rate, a value of 0.51 was calculated for f_R. From 1956 use rate data, a factor of 0.36 was calculated for 1956. Extrapolating the increased rate of use from 1970 to 1980, a f_R value of 0.69 is estimated for 1980.

The internal dose conversion factors D_{nop} (rem/Ci ingested) were taken from Killough (Ki78). Values for the amount of standard man quantity of crop p that is produced annually per square meter of land were 1.0 E-3 man/m^2 (Ki76) for food crops, 1.5 E-3 man/m^2 (Du77) for milk, and 2.1 E-4 man/m^2 (Du77) for beef. Fractions of irrigated land used for each food crop (f_p) as assumed for this analysis were 0.5 for food crops, 0.25 for grazing milk cows, and 0.25 for grazing beef cows. These values of f_p are upper limits since a portion of the irrigated land will be used for non-food crops.

The parameters as previously discussed were substituted into the specific activity model equations and representative results are presented in Table 3.5-1. Values for the ratio S_{nop}/Q_{np} with f_R=0.5 were used in this analysis; however, values of the ratio with f_R=1.0 are also presented so that the upper bound of C-14 man-rem/Ci released to the river value could be shown. With f_R=1.0, the infinite total body environmental dose commitment per curie released to the river for the crop ingestion pathways was 471 man-rems/Ci of C-14 released to the river. This value of 471 is essentially the total man-rems/Ci of C-14 released to the river since C-14 S_{nop}/Q_{np} values for the drinking water and freshwater fish ingestion pathways are .39 man-rems/Ci and 2.9 man-rems/Ci respectively with the total body as the target organ. The infinite total body environmental dose commitment per Ci of C-14 released to the river can be compared with an infinite total body environmental dose commitment of 537 man-rem per curie of C-14 released to the atmosphere as $^{14}CO_2$(Ki77). We believe that the impact per curie of C-14 release to the atmosphere as carbon dioxide should be regarded as an upper limit of the impact of C-14 released to the biosphere. The calculated value of the infinite environmental dose commitment per curie released was lower for a curie released to the river than for a curie released to the air, so we believe that the calculated carbon-14 values for the river pathways are reasonable and probably conservative.

Since the release of C-14 to the land surface is expected to be at low temperature, RI_{np}'s from Table 3.5-1 were applied for the ingestion pathways 13-15 using equations described in Section 3.3.2. In a case where C-14 is resuspended from the land surface to the air as CO_2, then methods similar to the ones which will be discussed for the volcano/meteorite release mode could be applied for the land surface release mode. However, these methods have not been applied for the land surface release mode in our analysis.

TABLE 3.5-1:
Carbon-14 integrated intake per unit deposition on the soil surface and the total body infinite environmental dose commitment per curie released to the river for the crop ingestions pathways

Ingestion Pathway	RI_{np} $\left(\frac{\text{Ci intake}}{\text{Ci/m}^2\text{ deposited}}\right)$	$\frac{S_{nop}}{Q_{np}}$ (man-rems/Ci)	
		f_R=0.5	f_R=1.0
Food Crops	325	156	312
Beef	424	21	43
Milk	161	58	116

For the volcano/meteorite release mode, (subpathways 17-30), environmental dose commitments to the world population were calculated using a diffusion-type model of the global carbon cycle developed by Killough (Ki77). For the volcano/meteorite release mode, we assume that the release will be at high temperature and that the C-14 would oxidize to CO_2 and become a part of the world carbon cycle. Values of the total body environmental dose commitment per curie of C-14 released to the atmosphere have been calculated by Fowler (Fo79) using the Killough model (Ki77). It is estimated that the ingestion pathway contributes 99 percent of the carbon-14 specific activity dose equivalent rate (Fo76). For estimating EDC, a cubic spline was fit to Fowler's curve of worldwide EDC to the total body per curie versus time after release. This cubic spline procedure yields the following equations for worldwide total body EDC vs time after C-14 placement in a repository:

for $10 \leq t-t_v < 100$ yr:

$$DTB_{14} = \exp\begin{bmatrix} 1.920 + 0.651[\ln(t-t_v) - 2.303] \\ -0.04485[\ln(t-t_v) - 2.303]^2 + 0.01109[\ln(t-t_v) - 2.303]^3 \end{bmatrix} \tag{3.5-5}$$

for $100 \leq t-t_v < 1{,}000$ yr:

$$DTB_{14} = \exp\begin{bmatrix} 3.316 + 0.6208[\ln(t-t_v) - 4.605] \\ +0.03172[\ln(t-t_v) - 4.605]^2 - 0.01056[\ln(t-t_v) - 4.605]^3 \end{bmatrix} \tag{3.5-6}$$

for $1{,}000 \leq t-t_v < 7{,}000$ yr:

$$DTB_{14} = \exp\begin{bmatrix} 4.785 + 0.5988[\ln(t-t_v) - 6.908] \\ -0.04126[\ln(t-t_v) - 6.908]^2 + 0.004198[\ln(t-t_v) - 6.908]^3 \end{bmatrix} \tag{3.5-7}$$

for $7{,}000 \leq t-t_v < 10{,}000$ yr:

$$DTB_{14} = \exp \begin{bmatrix} 5.825 + 0.4859[\ln(t-t_v) - 8.8537] \\ -0.01675[\ln(t-t_v) - 8.8537]^2 - 0.1544[\ln(t-t_v) - 8.8537]^3 \end{bmatrix} \quad (3.5\text{-}8)$$

for $10{,}000 \leq t-t_v < 40{,}000$ yr:

$$DTB_{14} = \exp \begin{bmatrix} 5.989 + 0.4153[\ln(t-t_v) - 9.2103] \\ -0.1817[\ln(t-t_v) - 9.2103]^2 + 0.02385[\ln(t-t_v) - 9.2103]^3 \end{bmatrix} \quad (3.5\text{-}9)$$

for $40{,}000 \leq t-t_v < 100{,}000$ yr:

$$DTB_{14} = \exp \begin{bmatrix} 6.279 + 0.04890[\ln(t-t_v) - 10.597] \\ -0.08246[\ln(t-t_v) - 10.597]^2 + 0.04059[\ln(t-t_v) - 10.597]^3 \end{bmatrix} \quad (3.5\text{-}10)$$

for $t-t_v \geq 100{,}000$ yr:

$$DTB_{14} = 537.0 \quad (3.5\text{-}11)$$

The organ specific EDC for C-14 releases is estimated by multiplying the total body EDC (DTB_{14} as obtained from equations 3.5-5 through 3.5-11) in man-rems per curie released by the ratio of organ dose commitment factor to total body dose commitment factor for ingestion ($D_{C\text{-}14,\ o,\ ingestion}/D_{C\text{-}14,\ total\ body,\ ingestion}$). The equation is

$$\frac{S_{no(17-30)}}{Q_{(17-30)}} = \frac{D_{C\text{-}14,\ o,\ ingestion}}{D_{C\text{-}14,\ total\ body,\ ingestion}} DTB_{14} \quad (3.5\text{-}12)$$

Equation 3.5-12 can be multiplied by f_{LL}, f_{AL}, and f_{AW} to estimate the C-14 EDC for the volcano/meteorite releases for releases directly to land, releases to air over land, and releases to air over water.

Section 4.0: DOSIMETRY AND HEALTH EFFECTS CONVERSION FACTORS

Dose commitment factors (DCF), or dose rate factors, and fatal or genetic health effects conversion factors are applied with each of the pathway equations discussed in Section 3. The sources of these factors will be discussed in this section.

4.1 Analytical Treatment of Daughter Product Buildup During Environmental Transport

Daughter product buildup during environmental transport was not addressed rigorously in the 30 pathway equations discussed in Section 3. An examination of the decay schemes for the nuclides revealed that, in general, the nuclides either (a) had stable daughters, (b) had daughters that were very short-lived compared to the parent, or (c) had a very long-lived first or second daughter. The following techniques were applied as an approximate method of handling daughter product ingrowth during environmental transport. For case (a), no action to account for daughter product buildup was required. In case (b), we assumed that the daughter was in secular equilibrium with the parent and that an equal quantity of daughter was present with the parent at all locations of the parent in the environment. Obviously this is a simplifying assumption, since daughter products may behave differently than the parents in the environment. The dose factors for daughters were added to the dose factors for the parent in cases where the daughters were dosimetrically significant. In case (c), calculations indicated that a significant buildup of the long-lived daughters (and, therefore, the daughters beyond the first long-lived daughters) would not occur during the residence time of the parent in the available environment. The available environment is that portion of the environment where the material would be available to man. For example, radionuclides present within the root zone of the soil would be in the available environment, but radionuclides that have moved below the root zone would have left the available environment. Thus, the dose factors for long-lived daughters (and daughters in the decay chain beyond a long-lived daughter) were not added to the dose factors for the parent. Any short-lived daughters in the decay chain between the parent and the first long-lived daughter are handled as described for case (b) above. The specific treatment of daughter products for each parent nuclide in this analysis is specified in Appendix A.

4.2 Dose Commitment Factors and Dose Rate Factors

For each of the 30 pathways, either internal doses occur due to inhalation or ingestion of radionuclides or external doses are delivered due to ground contamination or air submersion. Thus, for each radionuclide considered in this analysis, dose commitment factors for inhalation (solubility classes Y and W) and ingestion are needed. These factors express the 50-year dose commitment for the intake via inhalation or ingestion of a unit quantity of radionuclides. External dose rate factors are needed for each nuclide for exposure to a contaminated ground surface and for submersion in air. These factors express the dose rate per unit radionuclide activity on the ground or in the air. The dosimetry factors are needed for each organ considered in these calculations. In many cases, the dosimetry factors were also needed for daughter products so that these factors could be added to those for the parent as discussed in Section 4.1.

The symbol for the dosimetry factors (both the dose commitment factors and the external dose rate factors) is D_{nop}. The subscripts signify that the dosimetry factors are functions of radionuclide (n), organ (o), and pathway (p).

For internal dose commitment calculations, the primary reference for the dosimetry factors is NUREG/CR-0150, Vol. 1 (Ki78), and the draft of Vol. 2 (ORNL78). Internal dosimetry factors for radionuclides not included in NUREG/CR-0150 are taken from other references as listed in Appendix B. For the inhalation dosimetry factors taken from NUREG/CR-0150, the tables for AMAD=1 micron were applied. For the volcano/meteorite and land surface release modes, the insoluble Class Y inhalation dosimetry factors (labeled Inhalation 1) were used. For the river release mode, the Class W dosimetry factors, for more soluble compounds (labeled Inhalation 2), were used. Class Y dosimetry factors were listed in the Inhalation 1 category for all nuclides where they were available, and Class W dosimetry factors were listed in the Inhalation 2 category where they were available. However, for some radionuclides only Class D or Class D and Class W inhalation dosimetry factors were listed in NUREG/CR-0150. In these cases, the factors for the lowest solubility class available were applied. For example, if inhalation dosimetry factors were available for Class D and Class W but not for Class Y, the Class W factors were listed in both the Inhalation 1 and the Inhalation 2 categories.

References other than NUREG/CR-0150 as listed in Appendix B did not list inhalation dosimetry factors as a function of solubility classes Y, W, and D. However, in some cases, factors were listed for "soluble" and "insoluble" categories. When this was the case, the "insoluble" dosimetry factors were listed in the Inhalation 1 category and "soluble" dosimetry factors were listed in the Inhalation 2 category. Where only a single factor was listed, it was applied for both the Inhalation 1 and the Inhalation 2 categories.

NUREG/CR-0150 does not contain any dosimetry factors for external dose due to ground contamination or for external air submersion. The primary reference used for these dose rate factors was ORNL-4992 (Ki76). ORNL-4104 (Co67) was used for two or three radionuclides that were not included in ORNL-4992.

In some of the references used, dosimetry factors were not given for all organs considered in the analysis. This occurs for both the internal and the external dose pathways. In these cases, the whole body dosimetry factors were applied for these organs. This method results in an approximation to the organ dose, but we prefer using this approximation to neglecting these organ doses.

Included in Appendix B is a tabulation of all the dosimetry factors used in our analysis and the references for those dosimetry factors.

Neptunium-237 is a nuclide which deserves special mention in this document. In ICRP Report 30 (ICRP80) the value for absorption through the gut (f_1) is 10^{-2}. This is a 100-fold increase over the previous value of 10^{-4} recommended by ICRP in ICRP Report 2 (ICRP60). According to Cohen, this increase in f_1 plus the high cancer risk factor for the liver quoted in BEIR III have caused Np-237 to become a principal nuclide of concern in various assessments of the health effects from disposing of high-level radioactive waste (Co82). In ICRP30, it is mentioned that a value for f_1 of 10^{-3} may be more appropriate for trace quantities of the element or for neptunium incorporated in food. Information published subsequent to the publication of ICRP30 (Th82a, Th82b) suggests that 10^{-3} is probably the most appropriate value for f_1 for neptunium for low environmental levels. The internal dose conversion factors for Np-237 utilized by EPA in this report are based on an f_1 of 10^{-3} and EPA believes, based on current information, that this is the best value to use in these calculations. EPA is aware that ICRP Committee 2 has established a task group to recommend the most appropriate values of f_1's for actinides and that the NCRP has recently established a task group on neptunium. EPA will consider the recommendations, when they become available, of both of these committees in future analyses concerning the disposal of high-level radioactive waste.

4.3 Health Effects Conversion Factors

In this report fatal cancers and first generation genetic effects have been estimated from the environmental dose commitments calculated for the 30 pathways. These are the health effects committed to the population at risk during the initial 10,000 years following emplacement of high-level radioactive waste in a repository. To estimate these health effects, the EDC's, which are a function of nuclide, organ, and pathway, are multiplied by the health effects conversion factors, which are a function of organ. This yields health effects as a function of nuclide, organ, and pathway, and these health effects may be summed over organs and over the pathways within a release mode to yield the estimated health effects (fatal cancers or first generation genetic effects*) for each nuclide and each EDC release mode. The organs included in calculating fatal cancers are bone, red marrow, lung, liver, GI-LLI, thyroid, kidney, and other soft tissue. Those included in estimating first generation genetic effects are ovaries and testes. The health effects conversion factors applied in this analysis were specified by our Bioeffects Analysis Branch and are listed in Table 4.3-1 below.

4.4 Revised Dosimetry and Risk Methodology

Since the technical analyses described in this report were performed, EPA has worked with the staff of the Oak Ridge National Laboratory to develop a revised methodology for evaluating dose-equivalents and risk for individuals and populations exposed to radiation. Technical reports summarizing this work are available for those persons interested in the details of EPA's revised methodology (Du80, Be81, Su81). In general, the revised methodology is not expected to significantly alter the health effects per Ci release information presented in Tables D-1 through D-4. If further evaluation of the effects of EPA's new methodology shows that revisions to Tables D-1 through D-4 are needed, these revisions will be included in the final report.

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*First-generation genetic effects are the genetic effects to the children of the generation exposed to the radiation.

TABLE 4.3-1:
Health effects conversion factors

Organ	Fatal Cancers (HE/person-rem)	First Generation Genetic Effects (HE/person-rem)
Bone	1 E-5	-
Red Marrow	4 E-5	-
Lung	4 E-5	-
Liver	1 E-5	-
GI-LLI wall	2 E-5	-
Thyroid	1 E-6	-
Kidney	1 E-5	-
All Other Soft Tissue	7 E-5	-
Ovaries	-	2 E-5
Testes	-	2 E-5

Section 5: DISCUSSION OF VALUES FOR PARAMETERS*

Some of the parameters used in these calculations appear in several of the 30 pathway equations. For this reason, it was decided that representative values for parameters would be discussed in this separate section rather than including the discussion in the sections describing the pathway EDC equations. It should be emphasized that, for many parameters, a range of values will be found in the literature. Where specific numbers are discussed in this section, these are the values that were used for the health effects calculations summarized in Appendix D and discussed in more detail in EPA's analysis of the population risks from geologic repositories (SmC82). In some cases, a wide range of values for a particular parameter was examined as part of the EPA analysis; these instances are identified below. The values used for these parameters and a summary of our health effects calculations are included in Appendix D.

λ_{Ln} is the rate at which radionuclides are leached from the waste into the ground water in the repository and is assumed to be the same for all nuclides. A range of values from 1.0 E-2 yr^{-1} to 1.0 E-6 yr^{-1} was examined in the EPA analysis (SmC82) based on information furnished by the Arthur D. Little Company (Li77b).

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*The variables used in this section are defined in the "Nomenclature" section, p. 102 ff.

t_{er} is the time after placement in a repository that leaching from the repository begins and usually corresponds to failure of the waste canister. Canister lifetimes ranging between 100 and 5000 years were considered in EPA's analysis of geologic repositories (SmC82). We assume t_{er} is the same for all radionuclides.

t_{ran} is the time required for radionuclides to travel from the repository to an aquifer. This time varies depending upon the situation being addressed in EPA's analysis of geologic repositories, but the time is usually on the order of a few years.

t_{arn} is the time required for material to travel from the aquifer to the river. The value chosen for t_{arn} is 760 R_n yr where R_n is the retardation factor for the nuclide being considered. R_n varies between 1 and 10,000 depending on the radionuclide and the situation being considered. Values for R_n are discussed in the A. D. Little report (Li77c) and in EPA's population risk assessment report (SmC82).

f_L is the fraction of the repository contents subject to leaching. This value can vary from a very small number (10^{-3} or less) to one, depending on the release mechanism being considered in EPA's analysis (SmC82).

Q_{on} is the initial activity of nuclide n in the repository at time t=0. The value for Q_{on} remains constant for various scenarios and will be discussed in the population risk assessment report (SmC82).

λ_{Dn} is the radioactive decay constant for nuclide n. The values for λ_{Dn} are calculated using half-life information from Lederer (Le67) (see Table 5-1).

t_{rn} is the sum of t_{er}, t_{ran}, and t_{arn} and would be calculated by adding these three terms.

f_{LL}, f_{AL}, and f_{AW} are the fractions of the total release for a volcano/meteorite event which are released to the land surface, the air-above-land, and the air-above-water, respectively. Values for these parameters change with various scenarios and will be addressed in the population risk assessment report (SmC82).

P_R is the number of people who drink water from the river and R is the river flow rate. The ratio P_R/R is needed in several equations, and it can be determined for the purpose of this generic evaluation without obtaining site specific data. Utilizing data from Annex D of the 1977 UNSCEAR Report (UN77), the annual flow rate of the rivers of the world is 3 E+16 liters/yr. If one assumes a constant world population of 10^{10} persons,* the ratio P_R/R is 3.3 E-7 person-yr/liter. This

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* The current world population is about 3.8 E9. However, an estimate of average world population during the time period involved in this calculation is 10^{10} people (UN77).

TABLE 5-1:
Radionuclide decay constants

Nuclide	n	$\lambda_{Dn}(yr^{-1})$
C-14	1	1.21 E-4
Ni-59	2	8.66 E-6
Sr-90	3	2.47 E-2
Zr-93	4	4.62 E-7
Tc-99	5	3.27 E-6
Sn-126	6	6.93 E-6
I-129	7	4.08 E-8
Cs-135	8	2.31 E-7
Cs-137	9	2.31 E-2
Sm-151	10	7.97 E-3
Ra-226	11	4.33 E-4
U-234	12	2.81 E-6
Np-237	13	3.24 E-7
Pu-238	14	8.06 E-3
Pu-239	15	2.84 E-5
Pu-240	16	1.05 E-4
Am-241	17	1.51 E-3
Pu-242	18	1.83 E-6
Am-243	19	8.72 E-5

value for the ratio P_R/R is midrange of values found for various river basins in the United States. These values ranged from a high for P_R/R of 7.08 E-7 for the Hudson-Delaware River area to a low of 2.82 E-8 for the Columbia River basin.

I_w is the per capita annual comsumption of drinking water and water-based drinks. The reference adult man drinking rate of water and water-based drinks is 1.65 liters/d (ICRP75), which yields a value of I_w of 603 liters/yr. Note that the fraction of the global flowing water drunk by the world population is approximately 2 E-4.

P_{FF} is the population eating freshwater fish from the river and I_f is the per capita freshwater fish annual consumption rate. The ratio of the population fish consumption rate (P_{FF} I_f) to the river flow rate (R) is needed for the calculation. The current freshwater fish consumption rate for the world is 3.8 E9 man-kg/yr (UN77). We assume that fish consumption will increase proportionately as the population increases from the present level of 3.8 E9 people. For an eventual world population of 10^{10} people, this yields an annual freshwater fish consumption rate of 10^{10} man-kg/yr. Considering the average flow rate of the rivers of the world, the ratio of the population freshwater fish consumption rate to the river flow rate is 10^{10}/3 E16 = 3.3 E-7 man-kg/liter.

CF_{np} is the bioaccumulation factor for fish or shellfish for nuclide n and pathway p. The reference used for CF_{np} for freshwater fish, ocean fish, and ocean shellfish is ORNL-4992 (Ki76), which is based on values listed by Thompson (Th72). For nuclides not listed in ORNL-4992, the reference was UCRL-50564, Rev.1 (Th72). The values of the bioaccumulation factors are listed in Table 5-2.

RI_{np}, as discussed in Section 3, is the symbol for the terrestrial food pathway factors generated using the AIRDOS-EPA computer code (Mo79). The values used for these factors are listed in Table 5-3.

The fraction of land used for various food crops is f_p. For the river pathway, irrigation water provides the source of radionuclides to land, so irrigated farmland is the only land of concern. We assume that 50 percent of the irrigated land is used for growing food crops; 25 percent for grazing milk cows; and 25 percent for grazing beef cows. For the non-river release modes, radionuclides reach the land surface via dispersion in air so that the values for the fraction, f_p, must include the portion of U.S. land surface used for farming. It was found that 45 percent of the U.S. land surface was used for farming in 1974 (Wo79). To obtain a value for f_p for the non-river release modes, 45 percent of the value of f_p applied for the river release mode was used. Thus, for the non-river release mode, it was assumed that 23 percent of the land is used for growing food crops; 11 percent for grazing milk cows; and 11 percent for grazing beef cows. The values selected for f_p are upper limits since for all release modes, part of the agricultural land will be used for non-food crops (e.g., cotton, etc.).

TABLE 5-2:
Bioaccumulation factors for freshwater fish and seafood

Nuclide	n	CF_{np} (Ci/kg per Ci/liter) Freshwater Fish	Ocean Fish	Ocean Shellfish
C-14	1	4.55E+3	1.00E+0	1.00E+0
Ni-59	2	1.00E+2	5.00E+2	1.00E+2
Sr-90	3	5.00E+0	1.00E+0	1.00E+0
Zr-93	4	3.33E+0	3.00E+1	1.00E+2
Tc-99	5	1.50E+1	1.00E+1	1.00E+2
Sn-126	6	3.00E+3	3.00E+0	3.00E+0
I-129	7	1.50E+1	2.00E+1	1.00E+2
Cs-135	8	4.00E+2	3.00E+1	5.00E+1
Cs-137	9	4.00E+2	3.00E+1	5.00E+1
Sm-151	10	2.50E+1	2.50E+1	1.00E+3
Ra-226	11	5.00E+1	5.00E+1	1.00E+2
U-234	12	1.00E+1	1.00E+1	1.00E+1
Np-237	13	1.00E+1	1.00E+1	1.00E+1
Pu-238	14	3.50E+2	3.50E+0	1.00E+2
Pu-239	15	3.50E+2	3.50E+0	1.00E+2
Pu-240	16	3.50E+2	3.50E+0	1.00E+2
Am-241	17	2.50E+1	2.50E+1	1.00E+3
Pu-242	18	3.50E+2	3.50E+0	1.00E+2
Am-243	19	2.50E+1	2.50E+1	1.00E+3

TABLE 5-3:
Radionuclide intake factors

Nuclide	RI_{np} (Ci intake per Ci/m^2 deposited) Food Crops	Milk	Meat
C-14	3.25E+2	1.61E+2	4.24E+2
Ni-59	3.95E+0	1.28E+0	7.72E+0
Sr-90	1.06E+1	1.04E+0	9.89E-2
Zr-93	3.11E+0	1.29E+1	4.17E+0
Tc-99	6.37E+0	2.77E+0	1.84E+0
Sn-126	3.80E+0	2.24E-1	1.13E+1
I-129	3.18E+0	1.61E+0	8.67E-1
Cs-135	6.70E+0	4.20E+0	7.95E+0
Cs-137	3.13E+0	1.11E+0	2.11E+0
Sm-151	3.02E+0	7.91E-4	6.00E-1
Ra-226	8.19E+0	1.33E-1	8.50E-2
U-234	1.36E+1	8.90E-2	7.73E-4
Np-237	2.85E+0	7.60E-4	2.30E-2
Pu-238	2.91E+0	8.29E-6	2.26E-6
Pu-239	4.68E+0	1.34E-5	3.65E-6
Pu-240	4.42E+0	1.28E-5	3.49E-6
Am-241	3.42E+0	6.76E-3	2.27E-4
Pu-242	4.77E+0	1.16E-5	8.00E-5
Am-243	5.06E+0	1.04E-2	3.52E-4

The fraction of the river flow used for irrigation, f_R, was set equal to 0.5. Fractions representative of irrigation water use in 17 western states were 0.36 for 1956 and 0.51 for 1970 (CRC73). By performing a linear extrapolation of this data to 1980, a value of f_R of 0.69 was obtained. However, we decided to use $f_R = 0.50$ (essentially, the 1970 value), since performing the linear extrapolation with only two data points seemed rather tenuous.

CP_p is the number of standard men that can be fed by raising crop p on a unit area of land. The quantity is obtained by dividing the agricultural productivity (kg/m^2-y) of land on which crops are raised by the annual consumption rate of an individual consuming the crop (kg/y-person). Values for CP_p can be obtained from information in two references (Ki76, Du77). In this analysis the value of CP_p for food crops is 10^{-3} man/m^2; for milk, 1.5 E-3 man/m^2; and for beef, 2.1 E-4 man/m^2.

PD_p is the population density for pathway p. The value used for PD_p is 6.67 E-5 person/m^2, which is the world average population density and was obtained by dividing the assumed world population of 10^{10} persons by the land surface area of the earth of 1.5 E14 m^2 (Wo79). This value was mid-range of population densities for various regions of the U.S. (Wo79).

RF is the resuspension factor for material resuspending from the ground surface to the air. It is defined as the ratio of air concentration to ground concentration, $X_n(t')/\phi_n(t')$, which is equal to λ_R/v_{gn} where λ_R is a rate constant for resuspension of radionuclides from ground to air and v_{gn} is the deposition velocity from air to land surface. The value of λ_R chosen for this analysis is 10^{-11} sec^{-1}, which should be representative of weathered material (Ne78); and the value used for v_{gn} to scope this problem is 10^{-2} m/sec. The resulting value of RF is 10^{-9} m^{-1}. Actually, λ_R and RF are functions of time, but the time dependent relationships were not known and constant values were used to represent the average values over the calculation interval. The value selected for λ_R is appropriate to dry land resuspension, so the dose due to resuspension from wet irrigated land will be conservatively high.

I_B is the standard man breathing rate. Based on information contained in ICRP 23 (ICRP75), a value of 8400 m^3/yr has been chosen for this parameter.

SOF is a factor that accounts for the reduction in external dose due to household shielding and occupancy. A conservative value of 1.0 has been chosen for this analysis for all release modes except the river release mode. For the river release mode, the area where external dose could be received is irrigated farm land. After considering the fraction of time a person might spend around irrigated land, we decided to assign a value of 0.33 to SOF for the river release mode.

The rate constant for transfer of nuclides from available to unavailable soil is λ_{Sn}. The value for λ_{Sn} is nuclide dependent and is determined by a method described by Baes (Ba79) using data supplied by Baes and by the Arthur D. Little Co. (Li77c). The values from the Arthur D. Little report are believed to be conservative. The values used for λ_{Sn} in this analysis are given in Table 5-4. Baes's model does not consider erosion of soil (and radionuclides) as a removal mechanism from the available layer of soil. For long time periods, erosion may be a significant removal mechanism which would make the Baes model conservative for this application. An additional consideration for external exposure from material deposited to ground is that the movement of radionuclides below the ground surface will reduce external exposure to persons due to the shielding of the earth.

The transfer rate coefficients used in the ocean model are γ_1 and γ_2. That for movement of water from the lower to the upper ocean compartment is γ_2 and the value of it used for this analysis is 6.25 E-4 yr^{-1}(Ma73). For movement of water from the upper to the lower ocean compartment, the transfer rate coefficient is γ_1, and the value applied for this analysis is 3.3 E-2 yr^{-1}, which is derived from the expression $\gamma_1 = \gamma_2$ (3925/75) where 3925 m is the assumed depth of the ocean lower compartment and 75 m is the assumed depth of the ocean upper compartment.

The relationship between γ_1 and γ_2 is derived by assuming that interchange of water between the upper and lower layers of the ocean results in no net transfer from one layer to the other, i.e., the mass of each layer remains the same. If we further assume that the density of

TABLE 5-4:
Leaching coefficients for radionuclides in soil

Element	Leaching Coefficient (yr^{-1})
C	.5
Ni	.015
Sr	.00955
Zr	.0005
Tc	1.27
Sn	.0045
I	.12
Cs	.0021
Sm (Rare Earth)	.002
Ra	.01
Th	.0001
U	.00035
Np	.05
Pu	.0005
Am	.0005

water in the upper and lower layer is equal close to the boundary between the layers, we can derive a value for γ_1 using the value for γ_2 and using conservation of mass.* The volume of water transport upward per year is equal to $\gamma_2 V_2$ = (6.25 E-4) (3925) (3.61 E14) = 8.9 E14 m^3/yr, where 3.61 E14 m^2 is the area of the oceans (CRC75).

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* For equal densities close to the boundaries of the two ocean layers, conservation of mass will also result in conservation of volume.

Similarly, the volume of water transported downward per year is equal to $\gamma_1 V_1$ = (3.3 E-2) (75) (3.61 E14) = 8.9 E14 m^3/yr. Since $\gamma_1 V_1 = \gamma_2 V_2$, then γ_1 (75) (3.61 E14) = γ_2 (3925) (3.61 E14) and $\gamma_1 = \gamma_2$ (3925/75).

SF_{1n} and SF_{2n} are the sedimentation coefficients from the upper layer and the lower layer of the ocean, respectively, for nuclide n. The treatment of sedimentation is taken from a report of the working group of the International Nuclear Fuel Cycle Evaluation (INFCE78), which states that the sedimentation coefficients are given by

$$SF_n = \frac{K_{Dn} \, v_s}{h_c}$$

where

K_{Dn} = distribution coefficient of the radionuclide on the sediment (dimensionless),

v_s = sedimentation velocity (m/y), given a value of 10^{-5}, and

h_c = average depth of the water column (m) .

Nuclide specific values of SF_{1n} and SF_{2n} are then

$SF_{1n} = (10^{-5}/75) \, K_{Dn}$ and $SF_{2n} = (10^{-5}/3925) \, K_{Dn}$, or

$SF_{1n} = 1.33 \text{ E-7 } K_{Dn}$ and $SF_{2n} = 2.54 \text{ E-9 } K_{Dn}$.

The K_{Dn} values that we used are more conservative than those in INFCE78 to allow for expected competition for adsorption sites by the sea water ions, especially Mg and Ca. In the absence of detailed experimental work on sorption, anionic ions were assigned K_{Dn} values of zero; major sea water ions were given K_{Dn} values of 1; and neptunium was also given a K_{Dn} of 1. The effect of the sea water ions on divalent ions and on cesium was approximated by reducing the desert soil K_{Dn} values given by

Arthur D. Little (Li77c) by a factor of 10. Since the monovalent and divalent sea water cations would be expected to have a smaller effect on the adsorption of polyvalent cations, the Arthur D. Little K_{Dn} values were reduced by a factor of 2 for trivalent ions and unchanged for tetravalent ions. The values of K_{Dn} used in this report are listed in Table 5-5.

TABLE 5-5:
Distribution coefficients for radionuclides on sediment

Element	K_{Dn}(milliliters/g)
C	0
Ni	8
Sr	2
Zr	2000
Tc	0
Sn	0
I	0
Cs	20
Sm (Rare Earth)	300
Ra	10
U	300
Np	1
Pu	2000
Am	1000

The ratio of the population seafood consumption rate (P_p I_p) to the ocean upper compartment volume (V_1) is needed in these calculations. P_p is the population eating seafood and I_p is the per capita seafood annual consumpion rate for pathway p (p = 9 for fish ingestion and p = 10 for shellfish ingestion). V_1 is the volume of the upper compartment of the ocean where it is assumed that the edible fish are harvested. For this generic analysis, average values for the world are used. For ocean fish, the projected average population consumption rate is 6 kg/yr$\cdot 10^{10}$ persons = 6 E10 kg-persons/yr and for ocean shellfish it is 1 kg/yr$\cdot 10^{10}$ persons = 1 E10 kg-persons/yr (UN77). The volume of the upper compartment of the ocean is obtained by multiplying the world ocean surface area of 3.6 E14 m^2 (CRC75) by the assumed depth of the upper compartment of the ocean of 75 m. The resulting volume is 2.7 E16 m^3 or 2.7 E19 liters. Thus the ratio $P_p.I_p/V_1$ is 2.2 E-9 kg-people/liter-yr for ocean fish and 3.7 E-10 kg-people/liter-yr for ocean shellfish.

The terms t_L and t_V represent the times after placement in a repository that radioactive material is transmitted to the land surface or into air for the land surface and the volcano/meteorite pathways, respectively. The values for t_L and t_V change with various scenarios. Discussion of these parameters will be included in the population risk assessment report (SmC82).

The average height of the troposphere is h_A. Tropospheric height ranges from 25000 ft (7600 m) to 60,000 ft (18,000 m) (Wo79). An average value of 13,000 m was selected for these calculations.

The deposition velocity from air to oceans is v_{wn}. In this analysis, a value of 2 cm/sec was used for all nuclides, which was derived from general deposition velocity information contained in Meteorology and Atomic Energy, 1968 (AEC68).

The rate constant for deposition from air to ocean is λ_{wn}, which is equal to v_{wn}/h_A. Thus, the value calculated for this analysis is 48.7 yr^{-1}.

REFERENCES

AEC68 U.S. Atomic Energy Commision, 1968, Meteorology and Atomic Energy, 1968 (Edited by D. H. Slade), USAEC Rep. TID-24190, (Springfield, VA: NTIS).

AEC73 U.S. Atomic Energy Commission, 1973, "Draft Environmental Statement Concerning Proposed Rule Making Action: Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As-Low-As-Practicable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents", (Springfield, VA: NTIS).

Ba79 Baes C.F. III, 1979, "The Soil Loss Constant λ_s Due to Leaching from Soils", in: A Statistical Analysis of Selected Parameters for Predicting Food Chain Transport and Internal Doses of Radionuclides (Edited by F. O. Hoffman and C. F. Baes III) USNRC Rep. ORNL/NUREG/TM-282, pp. 85-92, USNRC (Springfield, VA: NTIS).

Be81 Begovich C.L., Eckerman K.F., Schlatter E.C., Ohr S.Y. and Chester R.O., 1981, "DARTAB: A Program to Combine Airborne Radionuclide Environmental Exposure Data with Dosimetric and Health Effects Data to Generate Tabulations of Predicted Health Impacts", USDOE Rep. ORNL-5692, Oak Ridge National Laboratory, (Springfield, VA: NTIS).

Bo71 Booth R.S., Kaye S.V. and Rohwer P.S., 1971, "A Systems Analysis Methodology for Predicting Dose to Man from a Radioactively Contaminated Terrestrial Environment" in: Proceedings of the Third National Symposium on Radioecology. (Edited by D.J. Nelson) Oak Ridge, TN, 10-12 May 1971, USAEC Rep. CONF - 710501-P2, pp. 877-893, USAEC (Springfield, VA: NTIS).

Co67 Cowser K.E., Kaye S. V., Rohwer P.S., Snyder W.S. and Struxness E.G., 1967, "Dose-Estimation Studies Related to Proposed Construction of an Atlantic-Pacific Interoceanic Canal with Nuclear Explosives: Phase I", USAEC Rep. ORNL-4101, Oak Ridge National Laboratory, (Springfield, VA: NTIS).

Co82 Cohen B.L., 1982, "Effects of ICRP Publication 30 and the 1980 BEIR Report on Hazard Assessments of High-Level Waste", Health Physics, Vol. 42, No. 2, February 1982,, pp. 133-143.

CRC73 The Chemical Rubber Company, 1973, CRC Handbook of Environmental Control (Edited by R.G. Bond and C.P. Straub), (Cleveland, OH: CRC Press).

CRC75 The Chemical Rubber Company, 1975, Handbook of Chemistry and Physics (Edited by R.C. Weast), (Cleveland, OH: CRC Press).

Du77 Dura V. P., Simmons G.L., Julian S.K. and Meyer S.P., 1977, "Costs and Effectiveness of Protective Actions for Six Generic Land Types Contaminated with a Radionuclide Deposition," Report for USEPA Contract 68-01-3549, Science Applications, Inc. Rep. SAI-77-539-LJ/F, (LaJolla, CA).

Du80 Dunning D.E., Leggett R.W. and Yalcintas M.G., 1980, "A Combined Methodology for Estimating Dose Rates and Health Effects from Exposure to Radioactive Pollutants", USDOE Rep. ORNL/TM-7105, Oak Ridge National Laboratory, (Springfield, VA: NTIS).

EPA82 U.S. Environmental Protection Agency, 1982, "Draft Environmental Impact Statement for Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes", USEPA Rep. EPA 520/1-82-025, (Washington, DC: USEPA).

Fo76 Fowler T.W., Clark R.L., Gruhlke J.M. and Russell J.L., 1976, "Public Health Considerations of Carbon-14 Discharges from the Light-Water-Cooled Nuclear Power Reactor Industry", USEPA Technical Note ORP/TAD-76-3, (Washington, DC: USEPA).

Fo79 Fowler T.W. and Nelson C.B., 1979, "Health Impact Assessment of Carbon-14 Emissions from Normal Operations of Uranium Fuel Cycle Facilities", USEPA Rep. EPA 520/5-80-004, (Montgomery, AL: USEPA).

Go82 Goldin A.S., Serini B.L., Struckmeyer R.K., Hung C.Y. and Smith C.B., 1982, "Potential Individual Doses from Disposal of High-Level Radioactive Wastes in Geologic Repositories", USEPA Rep. EPA 520/1-82-026, (Washington, DC: USEPA).

Ho77 Hoenes G.R. and Soldat J.K., 1977, "Age-Specific Radiation Dose Commitment Factors for a One-Year Chronic Intake", USNRC Rep. NUREG-0172, Battelle Pacific Northwest Laboratories, (Springfield, VA: NTIS).

Ho80 Hoffman F.O., Huckabee J.W., Lucas D.M., Garten C.T. Jr., Scott T.G., Walker R.L., Gouge P.S. and Holmes C.V., 1980, "Sampling of Technetium-99 in Vegetation and Soils in the Vicinity of Operating Gaseous Diffusion Facilities", ORNL/TM-7386, Oak Ridge National Laboratory, (Oak Ridge, TN: USEPA).

Ho82 Hoffman F.O., Garten C.T. Jr., Huckabee J.W., and Lucas D.M., 1982, "Interception and Retention of Technetium by Vegetation and Soil", *Journal of Environmental Quality*, Vol. 11, no. 1, January-March 1982, pp. 134-141.

ICRP60 International Commission on Radiological Protection, 1960, ICRP Publication 2, *Report of Committee II on Permissible Dose for Internal Radiation (1959)*, (Elmsford, NY: Pergamon Press).

ICRP75 International Commission on Radiological Protection, 1975, ICRP Publication 23: *Report of the Task Group on Reference Man*, (Elmsford, NY: Pergamon Press).

ICRP77 International Commission on Radiological Protection, 1977, ICRP Publication 26: *Recommendations of the International Commision on Radiological Protection*, (Elmsford, NY: Pergamon Press).

ICRP80 International Commission on Radiological Protection, 1980, ICRP Publication 30 (with supplements), *Limits for Intakes of Radionuclides by Workers*, (Elmsford, NY: Pergamon Press).

INFCE78 International Nuclear Fuel Cycle Evaluation, February 13, 1978, "Collective Dose Commitments from the Disposal of High-Level Radioactive Wastes," INFCE/WG.7/7, Section 35.

Ki76 Killough G.G. and McKay L.R., 1976, "A Methodology for Calculating Radiation Doses from Radioactivity Released to the Environment", USERDA Rep. ORNL-4992, Oak Ridge National Laboratory, (Springfield, VA: NTIS).

Ki77 Killough G.G., 1977, "A Diffusion - Type Model of the Global Carbon Cycle for the Estimation of Dose to the World Population from Releases of Carbon-14 to the Atmosphere," USERDA Rep. ORNL-5269, Oak Ridge National Laboratory, (Springfield, VA: NTIS).

Ki78 Killough G.G., Dunning D.E. Jr., Bernard S.R. and Pleasant J.C., 1978, "Estimates of Internal Dose Equivalent to 22 Target Organs for Radionuclides Occurring in Routine Releases from Nuclear Fuel-Cycle Facilities", USAEC Rep. NUREG/CR-0150, ORNL/NUREG/TM-190, (Springfield, VA: NTIS).

Le67 Lederer C.M., Hollander J.M. and Perlman I., 1967, *Table of Isotopes*, (New York, NY: John Wiley and Sons, Inc.).

Li77a Little A.D. Inc., 1977, "Technical Support of Standards for High-Level Radioactive Waste Management: Volume A-Source Term Characterization", USEPA Rep. EPA 520/4-79-007A, (Washington, DC: USEPA).

Li77b Little A.D. Inc., 1977, "Technical Support of Standards for High-Level Radioactive Waste Management: Volume B-Engineering Controls", USEPA Rep. EPA 520/4-79-007B, (Washington, DC: USEPA).

Li77c Little A.D. Inc., 1977, "Technical Support of Standards for High-Level Radioactive Waste Management: Volume C-Migration Pathways", USEPA Rep. EPA 520/4-79-007C, (Washington, DC: USEPA).

Li80 Little A.D. Inc., 1980, "Technical Support of Standards for High-Level Radioactive Waste Management: Volume D-Release Mechanisms", USEPA Rep. EPA 520/4-79-007D, (Washington, DC: USEPA).

Ma73 Machta L., 1973, "Prediction of CO_2 in the Atmosphere", in *Carbon and the Biosphere* (Edited by G.M. Woodwell and E.V. Pecan) Upton, NY, 16-18 May 1972, USAEC Rep. CONF-720510, pp. 21-31, (Springfield, VA: NTIS).

Mo79 Moore R.E., Baes C.F. III, McDowell-Boyer L.M., Watson A.P., Hoffman F.O., Pleasant J.C. and Miller C.W., 1979, "AIRDOS - EPA: A Computerized Methodology for Estimating Environmental Concentrations and Dose to Man from Airborne Releases of Radionuclides", USEPA Rep. EPA 520/1-79-009, Oak Ridge National Laboratory, (Washington, DC: USEPA).

Ne78 Nelson C.B., Davis R. and Fowler T.W., 1978, "A Model to Assess Population Inhalation Exposure from a Transuranium Element Contaminated Land Area", in: *Selected Topics: Transuranium Elements in the General Environment*", USEPA Technical Note ORP/CSD-78-1, pp. 213-280, (Washington, DC: USEPA).

NRC77 U.S. Nuclear Regulatory Commission, 1977, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I", USNRC Regulatory Guide 1.109, revision 1, (Washington, DC: USNRC).

ORNL78 Personal Communication, G.G. Killough - Oak Ridge National Laboratory to C.B. Nelson - U.S. Environmental Protection Agency, November 1978.

SmC82 Smith C.B., Egan D.J., Williams W.A., Gruhlke J.M., Hung C.Y. and Serini B.L., 1982, "Population Risks from Disposal of High-Level Radioactive Wastes in Geologic Repositories", USEPA Rep. EPA 520/3-80-006, (Washington, DC: USEPA).

Su81 Sullivan R.E., Nelson N.S., Ellett W.H., Dunning D.E., Jr., Leggett R.W., Yalcintas M.G. and Eckerman K.F., 1981, "Estimates of Health Risk from Exposure to Radioactive Pollutants", USDOE Rep. ORNL/TM-7745, Oak Ridge National Laboratory, (Springfield, VA: NTIS).

Th72 Thompson S.E., Burton C.A., Quinn D.J. and Ng Y.C., 1972, "Concentration Factors of Chemical Elements in Edible Aquatic Organisms", USAEC Rep. UCRL-50564/Rev. 1, Lawrence Livermore Laboratory, (Springfield, VA: NTIS).

Th82a Thompson R.C., 1982, "Neptunium - The Neglected Actinide: A Review of the Biological and Environmental Literature", *Radiation Research*, Vol. 90, No. 1, April 1982, pp. 1-32.

Th82b Thompson R.C., 1982, "Neptunium - The Neglected Actinide: Corrections and Extensions," Radiation Research, Vol. 92, December 1982, pp. 620-621.

UN77 United Nations, 1977, Sources and Effects of Ionizing Radiation: UNSCEAR 1977 Report, United Nations Publication Sales No. E.77.IX.1, United Nations Scientific Committee on the Effects of Atomic Radiation, (New York, NY: United Nations).

We73 Wetzel R.G. and Rich P.H., 1973, "Carbon in Freshwater Systems", in: Carbon and the Biosphere (Edited by G.M. Woodwell and E.V. Pecan) Upton, NY, 16-18 May 1972, USAEC Rep. CONF - 720510, pp. 241-263, (Springfield, VA: NTIS).

Wo79 Newspaper Enterprise Association, Inc., 1978, The World Almanac and Book of Facts 1979, (New York, NY).

NOMENCLATURE

SUBSCRIPTS:

Unless specifically stated otherwise, these subscripts refer to the following:

a	aquifer
ar	aquifer-to-river
A	air
AL	air-over-land
AW	air-over-water
B	breathing
c, 14, and C-14	radionuclide C-14
D	radioactive decay
er	repository breaching event
f and FF	freshwater fish
g	air to ground
L	leaching (except refers to land surface pathway when used with variable t)
LL	directly to land
LS	land surface
n	nuclide
o	organ
p	pathway
ra	repository-to-aquifer
R	river (except refers to resuspension when used with variable λ)
s	soil
v	volcano/meteorite event
w	water or ocean
W	water

SUBSCRIPTS (continued):

0	initial condition
1	upper ocean compartment
2	lower ocean compartment

SYMBOLS:

A	area of land irrigated (m^2)
A_L	land surface area for earth (m^2)
A_r	land area on which resuspended material is deposited (m^2)
A_w	ocean surface area for earth (m^2)
A_1	initial release rate of radionuclides into the ocean from the river (Ci/y)
C_c	concentration of stable carbon in freshwater (gm C/liter)
CF_{np}	bioaccumulation factor for fish or shellfish for nuclide n and pathway p (Ci/kg per Ci/liter)
CP_p	the number of persons (standard men) who can be fed from the quantity of crops (pathway p) raised annually on a unit area of land (man fed/m^2)
$D'(t)$	dose commitment rate as a function of time (rem/yr)
D_{C-14}, total body, ingestion	C-14 ingestion dose commitment factor with the total body as the target organ (rem per Ci ingested)
D_{C-14}, o, ingestion	C-14 ingestion dose commitment factor for target organ o (rem per Ci ingested)
D_{nop}	dosimetry factor for nuclide n, organ o, and pathway p: for inhalation and ingestion (rem/Ci intake); for external air submersion (rem/yr per Ci/m^3); for external ground contamination (rem/yr per Ci/m^2)
DI'_{nop}	annual dose to an individual for nuclide n, organ o, and pathway p (rem/yr).
DWB_{14}	total body EDC as a function of integration time for C-14 released for the volcano/meteorite pathway (man rem/Ci released)

SYMBOLS (continued):

f_A	fraction of total release for the volcano/meteorite release mode which goes into air (dimensionless)
f_{AL}	fraction of total release which goes to air over land (dimensionless)
f_{AW}	fraction of total release which goes to air over water (dimensionless)
f_{cp}	fraction of the standard man organ C-14 specific activity that is maintained by food intake pathway p (dimensionless)
f_L	fraction of repository which is being leached (dimensionless)
f_{LL}	fraction of total release which goes directly onto land (dimensionless)
f_{LS}	fraction of the repository contents which is released to the land surface (dimensionless)
f_p	fraction of land used for various food crops for pathway p (dimensionless)
f_R	fraction of river flow used for irrigation (dimensionless)
$F_n(t')$	quantity of radionuclide n deposited to ground per unit area integrated to time t' (Ci/m^2)
$F'_n(t)$	flux of nuclide n to ground as a function of time (Ci/m^2-yr)
FHE	fatal cancers for nuclide n for the release mode under consideration (fatal cancers)
GE	first generation genetic effects for nuclide n, for the release mode under consideration (genetic effects)
h_A	height of troposphere (m)
HECON_o	health effects conversion factor for organ o (health effects/rem)
I_B	standard man breathing rate (m^3/yr)
I_c	total dietary intake rate of carbon by standard man (gm C/yr)
I_f	freshwater fish annual consumption rate (kg/yr-person)
I_p	seafood annual consumption rate for pathway p (kg/yr)

SYMBOLS (continued):

I_W	annual individual water ingestion rate (liters/yr-person)
$N(D',t)$	size of the population exposed to dose commitment rate $D'(t)$ at time t (persons)
P_{Ap}	population subjected to inhalation of radionuclides for pathway p (persons)
P_{FF}	population eating freshwater fish from the river (persons)
P_{Fp}	population eating food included in pathway p (persons)
P_p	population eating seafood for pathway p (persons)
P_R	population drinking water from river (persons)
PD_p	population density for pathway p (man/m^2)
q_{1n}	quantity of radionuclide n in the upper compartment of the ocean for releases to ocean from rivers (Ci)
q_{2n}	quantity of radionuclide n in the lower compartment of the ocean for releases to ocean from rivers (Ci)
$Q'(t')$	source term from ground to air at time t' (Ci/yr)
Q_{An}	quantity of radionuclide n in the air-over-ocean compartment (Ci)
Q'_{anp}	rate of entry of radionuclide n to an aquifer for pathway p (Ci/yr)
$Q'_D(t')$	source term from ground to air at time t' corrected for depletion (Ci/yr)
Q_{Ln}	quantity of radionuclide n in the air-over-land compartment (Ci)
Q_{np}	total release of radionuclide n to environment into pathway p (Ci). For the land surface and air pathway, the release is instantaneous; for the river and ocean pathway, the release is integrated from time of placement in the repository out to time t.
Q_n	total release of radionuclide n to the environment for the release mode under consideration (Ci) Note: $Q_n = Q_{np}$ since the releases considered for the different pathways within a release mode are all equal.
Q'_{np}	rate of entry of radionuclide n into the river or ocean (Ci/y)
Q_{on}	initial inventory of radionuclide n in the repository (Ci)

SYMBOLS (continued):

Q_p	total release of C-14 to the land surface for pathway p (Ci)
Q_{sn}	quantity of radionuclide n in the soil root zone (Ci)
Q_{1n}	quantity of radionuclide n in the upper compartment of the ocean for releases to ocean from air (Ci)
Q_{2n}	quantity of radionuclide n in the lower compartment of the ocean for releases to ocean from air (Ci)
r	radial distance from source of radionuclide to point of interest (m)
r_d	an empirical expression which is given in equation 3.3.2-4
R	river flow rate (liters/yr)
RF	resuspension factor (m^{-1})
RI_{np}	intake of nuclide n by an individual (standard man) for the crop represented by pathway p and for a unit acute deposition to the surface (Ci intake per Ci/m^2 deposited on soil surface)
S_{nop}	environmental dose commitment to the population for nuclide n, organ o, and pathway p, integrated to time t (man-rem)
S'_{nop}	dose commitment rate to the population for nuclide n, organ o, and pathway p (man-rem/yr)
SF_{1n}	sedimentation coefficient from upper layer of ocean for radionuclide n (yr^{-1})
SF_{2n}	sedimentation coefficient from lower layer of ocean for radionuclide n (yr^{-1})
SOF	household shielding and occupancy factor (dimensionless)
t	time after placement in repository at which EDC is calculated (yr)
t'	time after release of radionuclides to the environment at which EDC is calculated (yr)
t_{arn}	time for radionuclide n to travel from aquifer to river (yr)
t_{er}	time after placement in repository that radioactive material leaves the repository (yr)

SYMBOLS (continued):

t_L	time after placement in repository that the material comes to the surface for the land surface release mode (yr)
t_{ran}	time for radionuclide n to travel from repository to aquifer (yr)
t_{Rn}	time after placement in repository that radionuclide n enters the river or ocean (yr)
t_V	time after placement in the repository that the material enters into the land and air environment as the result of a volcano or meteorite (yr)
V_{AW}	volume of tropospheric air-over-water (m^3)
v_{gn}	deposition velocity from air to land surface (m/yr)
V_L	volume of tropospheric air over land (m^3)
v_{wn}	deposition velocity from air to ocean (m/yr)
V_1	volume of compartment 1 (upper compartment) of ocean (liters)
W	irrigation rate (liters/m^2-yr)
χ_{1n}	concentration of radionuclide n in the upper compartment of the ocean for releases to the ocean from air (Ci/liter)
$\chi_{in}(r,t')$	air concentration at point r and time t' due to resuspension at initial source (Ci/m^3)
χ_n	air concentration of radionuclide n due to resuspension from the ground surface at the location of interest and due to resuspension at the initial source and subsequent dispersion to the location of interest (Ci/m^3)
$(\chi/Q')_{r_n}$	atmospheric dispersion factor at the reference distance r_n (sec/m^3)
χ_{Rn}	air concentration of radionuclide n at the center of a uniformly contaminated area having a surface concentration $\phi_n(t)$ due to resuspension of radionuclides from the ground surface (Ci/m^3)
z	"fitting" exponent in empirical equation for $\chi_{in}(r,t')$
$\gamma 1$	transfer rate coefficient from upper to lower ocean (yr^{-1})
$\gamma 2$	transfer rate coefficient from lower to upper ocean (yr^{-1})

SYMBOLS (continued):

λ_{Dn}	radioactive decay constant for nuclide n (yr^{-1})
λ_{gn}	rate constant for deposition from air to ground (yr^{-1})
λ_{Ln}	leaching rate constant from repository (yr^{-1})
λ_R	rate constant for resuspension of nuclides from soil to air (yr^{-1})
λ_{Sn}	rate constant for transfer of nuclides from available to unavailable soil for nuclide n (yr^{-1})
λ_{Tn}	$\lambda_R + \lambda_{Dn} + \lambda_{Sn}$
λ_{wn}	rate constant for deposition from air to ocean (yr^{-1})
ϕ'_n	rate of change with time of ground surface concentration for radionuclide n (Ci/m^2-y)
ϕ_n	ground surface concentration of radionuclide n as a function of time (Ci/m^2)

APPENDIX A: METHODS FOR CONSIDERATION OF DAUGHTER PRODUCT INGROWTH

For each parent radionuclide discussed in this report, the method for considering daughter product ingrowth is given in this Appendix (also see the discussion in section 4.1).

Radionuclide	Method for Consideration of Daughter Product Ingrowth
C-14 ($T_{1/2}$ = 5730 yr)	stable daughter - no action required
Ni-59 ($T_{1/2}$ = 8 E4 yr)	stable daughter - no action required
Sr-90 ($T_{1/2}$ = 28.1 yr)	assume Y-90 ($T_{1/2}$ = 64 hr) is in secular equilibrium and add Y-90 dose factors to those for Sr-90.
Zr-93 ($T_{1/2}$= 1.5 E6 yr)	Nb-93m is produced in 95 percent of the decays. Nb-93m ($T_{1/2}$ = 13.6 yr) is an intermediate half-life daughter. There would not be significant buildup of Nb-93m for air inhalation and for air submersion. Thus, for these dose media, Nb-93m dose factors were not added to those for Zr-93. However, for the ground surface-external dose pathway, and the ingestion pathway, it is believed that significant buildup of Nb-93m could occur. For these dose media, Nb-93m was assumed to be in secular equilibrium and 95 percent of the dose factors for Nb-93m was added to the factors for Zr-93.
Tc-99 ($T_{1/2}$ = 2.1 E5 yr)	stable daughter - no action required.
Sn-126 ($T_{1/2}$ = 1 E5 yr)	assume Sb-126 ($T_{1/2}$ = 12.5 d) daughter is in secular equilibrium in the environment with Sn-126 and add Sb-126 dose factors to those for Sn-126.
I-129 ($T_{1/2}$ = 1.7 E7 yr)	stable daughter - no action required.
Cs-135 ($T_{1/2}$ = 3 E6 yr)	stable daughter - no action required.

Radionuclide	Method for Consideration of Daughter Product Ingrowth
Cs-137 ($T_{1/2}$ = 30 yr)	decays to Ba-137m 93.5 percent of the time. Assume that Ba-137m ($T_{1/2}$ = 2.55 min) is in secular equilibrium with Cs-137 and add 93.5 percent of dose factors for Ba-137m to the dose factors for Cs-137.
Ra-226 ($T_{1/2}$ = 1602 yr)	Very short-lived daughters of Ra-226 are Rn-222 ($T_{1/2}$ = 3.8 d), Po-218 ($T_{1/2}$ = 3 min), Pb-214 ($T_{1/2}$ = 27 min), Bi-214 ($T_{1/2}$ = 20 min), and Po-214 ($T_{1/2}$ = 164 μs). Assume these nuclides are in secular equilibrium with Ra-226 and add dose factors for these nuclides to those for Ra-226. Next daughter is Pb-210 ($T_{1/2}$ = 21 yr) which is an intermediate half-life daughter. There would not be a significant buildup of Pb-210 for air inhalation and for air submersion. Thus, for these dose media Pb-210 dose factors were not added to the Ra-226 factors. Also the dose factors for the two short-lived daughters of Pb-210 [Bi-210 ($T_{1/2}$ = 5 d) and Po-210 ($T_{1/2}$ = 138 d)] were not added to those for Ra-226 for air inhalation and air submersion. For the ground surface-external dose pathway and the ingestion pathway, it is believed that, in addition to the short-lived daughters, significant buildup of Pb-210 and the short-lived daughters Bi-210 and Po-210 could occur. For these dose media, these three daughters were assumed to be in secular equilibrium with Ra-226 and the dose factors for these daughters were added to the factors for Ra-226. We realize that treating Rn-222 in the manner described leads to approximate results. However, we believe that it is better to analyze all daughter products in a simplified manner rather than to entirely exclude daughters from the analysis.
Sm-151 ($T_{1/2}$ = 87 yr)	Stable daughter - no action required.

Radionuclide	Method for Consideration of Daughter Product Ingrowth
U-234 ($T_{1/2}$ = 2.5E5 yr)	First daughter is Th-230 ($T_{1/2}$ = 8 E4 yr). It is believed that the lifetime of the U-234 in the available environment (the portion of the environment where the material would be available to man) will be short compared to the half-life of Th-230. Thus, no significant levels of Th-230 should build up before the U-234 disappears from the available environment. No modifications are required to the U-234 dose factors.
Np-237 ($T_{1/2}$= 2.14 E6 yr)	Assume Pa-233 ($T_{1/2}$ = 27 d) is in secular equilibrium and add Pa-233 dose factors to those for Np-237. U-233 ($T_{1/2}$ = 1.62 E5 yr) (and daughters beyond U-233) levels in available environment should be negligible (see discussion for U-234) and no further action required on Np-237 dose factors.
Pu-238 ($T_{1/2}$ = 86 y)	First daughter is U-234 ($T_{1/2}$ = 2.5 E5 yr). U-234 (and daughters) levels in available environment should be negligible (see discussion for U-234) and no action required on Pu-238 dose factors.
Pu-239 ($T_{1/2}$ = 2.4 E4 yr)	First daughter is U-235 ($T_{1/2}$ = 7.1 E8 yr). U-235 (and daughter) levels in available environment should be negligible (see discussion for U-234) and no action required on Pu-239 dose factors.
Pu-240 ($T_{1/2}$ = 6580 yr)	First daughter is U-236 ($T_{1/2}$ = 2.4 E7 yr). U-236 (and daughters) levels in available environment should be negligible (see discussion for U-234) and no action required on Pu-240 dose factors.
Am-241 ($T_{1/2}$ = 458 yr)	First daughter is Np-237 ($T_{1/2}$ = 2.1 E6 yr). Np-237 (and daughters) levels in available environment should be negligible (see discussion for U-234) and no action required on Am-241 dose factors.

Radionuclide	Method for Consideration of Daughter Product Ingrowth
Pu-242 ($T_{1/2}$ = 3.8 E5 yr)	First daughter is U-238 ($T_{1/2}$ = 4.5 E9 yr). U-238 (and daughters) levels in available environment should be negligible (see discussion for U-234) and no action required on Pu-242 dose factors.
Am-243 ($T_{1/2}$ = 7950 yr)	Assume Np-239 ($T_{1/2}$ = 2.3 d) is in secular equilibrium and add Np-239 dose factors to those for Am-243. Pu-239 ($T_{1/2}$ = 2.4 E4 yr) (and daughters) levels in available environment should be negligible (see discussion for U-234) and no further action required on Am-243 dose factors.

APPENDIX B: DOSIMETRY FACTORS

The dosimetry factors which were applied in these analyses are listed in Table B-1 and again in the sample computer program output shown in Appendix F. The references for the dosimetry factors are given in Table B-2. The references identified in Table B-2 are as follows:

NUREG/CR-0150	Killough G.G., Dunning D.E. Jr., Bernard S.R. and Pleasant J.C., 1978, "Estimates of Internal Dose Equivalent to 22 Target Organs for Radionuclides Occurring in Routine Releases from Nuclear Fuel-Cycle Facilities" USAEC Rep. NUREG/CR-0150, ORNL/NUREG/TM-190, Oak Ridge National Laboratory, (Springfield, VA: NTIS).
NUREG-0172	Hoenes G.R. and Soldat J.K., 1977, "Age-Specific Radiation Dose Commitment Factors for a One-Year Chronic Intake", USNRC Rep. NUREG-0172, Battelle Pacific Northwest Laboratories, Springfield, VA: NTIS).
ORNL-4992	Killough G.G. and McKay L.R., 1976, "A Methodology for Calculating Radiation Doses from Radioactivity Released to the Environment", USERDA Rep. ORNL-4992, Oak Ridge National Laboratory, (Springfield, VA: NTIS).
ORNL-4101	Cowser K.E., Kaye S.V., Rohwer P.S., Snyder W.S. and Struxness E.G., 1967, "Dose Estimation Studies Related to Proposed Construction of an Atlantic-Pacific Interoceanic Canal with Nuclear Explosives: Phase I", USAEC Rep. ORNL-4101, Oak Ridge National Laboratory, (Springfield, VA: NTIS).
ORNL-Draft	Personal Communication, G.G. Killough, Oak Ridge National Laboratory, to C.B. Nelson, U.S. Environmental Protection Agency, November 1978.

TABLE B-1:
Dosimetry factors

(INHAL1 & 2 AND INGEST=REM/CI INTAKE   EXT AIR=REM/Y PER CI/M**3   EXT GND=REM/Y PER CI/M**2)

NUCLIDE	PATHWAY	ORGAN									
		BONE	RED MARROW	LUNG	LIVER	GI-LLI	THYROID	KIDNEY	OTHER ORGAN	OVARIES	TESTES
C-14	INHAL1	8.46E+00	2.42E+01	6.18E+00	8.88E+00	7.22E+00	6.48E+00	7.92E+00	1.41E+01	5.29E+00	5.42E+00
	INHAL2	8.46E+00	2.42E+01	6.18E+00	8.88E+00	7.22E+00	6.48E+00	7.92E+00	1.41E+01	5.29E+00	5.42E+00
	INGEST	1.17E+03	3.38E+03	8.49E+02	1.23E+03	1.46E+03	8.89E+02	1.06E+03	1.92E+03	7.36E+02	7.23E+02
	EXT AIR	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
	EXT GND	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
NI-59	INHAL1	1.29E+04	2.15E+03	8.47E+03	4.98E+03	7.12E+02	2.15E+03	2.15E+03	2.15E+03	2.15E+03	2.15E+03
	INHAL2	1.29E+04	2.15E+03	8.47E+03	4.98E+03	3.56E+02	2.15E+03	2.15E+03	2.15E+03	2.15E+03	2.15E+03
	INGEST	9.67E+03	1.61E+03	1.61E+03	3.32E+03	9.70E+02	1.61E+03	1.61E+03	1.61E+03	1.61E+03	1.61E+03
	EXT AIR	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
	EXT GND	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
SR-90	INHAL1	3.21E+05	1.21E+05	8.54E+06	1.93E+04	9.31E+05	3.74E+03	3.74E+03	1.51E+05	3.74E+03	3.73E+03
	INHAL2	3.00E+06	1.10E+06	4.92E+04	1.49E+04	5.50E+04	1.54E+04	1.54E+04	2.41E+05	1.54E+04	1.54E+04
	INGEST	1.20E+06	4.30E+05	1.57E-02	5.71E+03	1.98E+05	5.99E+03	5.99E+03	9.50E+04	5.99E+03	5.99E+03
	EXT AIR	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
	EXT GND	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
ZR-93	INHAL1	1.47E+03	1.75E+03	5.85E+04	2.93E+03	7.16E+03	1.60E+03	1.36E+03	2.50E+03	1.04E+03	1.47E+02
	INHAL2	4.12E+03	2.46E+03	3.08E+04	2.11E+03	6.98E+03	1.32E+03	1.32E+03	2.13E+03	1.46E+03	4.95E+02
	INGEST	1.97E+02	3.34E+02	3.90E+01	1.43E+02	1.75E+04	1.69E+01	1.99E+02	2.47E+02	1.36E+03	1.34E+02
	EXT AIR	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
	EXT GND	1.78E+04	1.78E+04	1.78E+04	1.78E+04	1.78E+04	1.78E+04	1.78E+04	1.78E+04	1.78E+04	1.78E+04
TC-99	INHAL1	2.42E+02	2.15E+02	5.22E+04	4.21E+02	1.66E+03	9.46E+03	3.07E+02	8.87E+02	2.12E+02	2.12E+02
	INHAL2	2.42E+02	2.15E+02	5.22E+04	4.21E+02	1.66E+03	9.46E+03	3.07E+02	8.87E+02	2.12E+02	2.12E+02
	INGEST	3.61E+02	3.22E+02	0.00E-01	6.28E+02	3.20E+03	1.41E+04	4.58E+02	2.14E+02	3.17E+02	3.17E+02
	EXT AIR	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
	EXT GND	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
SN-126	INHAL1	1.58E+05	1.58E+05	1.27E+06	4.19E+03	7.60E+04	1.23E+03	6.16E+03	6.16E+03	6.16E+03	6.16E+03
	INHAL2	1.58E+05	1.58E+05	1.27E+06	4.19E+03	7.60E+04	1.23E+03	6.16E+03	6.16E+03	6.16E+03	6.16E+03
	INGEST	8.57E+04	8.57E+04	3.11E+03	1.69E+03	1.18E+05	4.99E+02	2.83E+03	2.82E+03	2.82E+03	2.82E+03
	EXT AIR	1.15E+07	1.15E+07	1.15E+07	1.15E+07	1.15E+07	1.15E+07	1.15E+07	1.15E+07	1.15E+07	1.15E+07
	EXT GND	2.09E+05	2.09E+05	2.09E+05	2.09E+05	2.09E+05	2.09E+05	2.09E+05	2.09E+05	2.09E+05	2.09E+05
I-129	INHAL1	5.79E+02	6.05E+02	7.88E+02	4.66E+02	4.28E+01	5.00E+06	4.49E+02	2.05E+03	3.78E+02	3.57E+02
	INHAL2	5.79E+02	6.05E+02	7.88E+02	4.66E+02	4.28E+01	5.00E+06	4.49E+02	2.05E+03	3.78E+02	3.57E+02
	INGEST	9.02E+02	9.42E+02	1.79E+02	7.24E+02	6.70E+01	7.80E+06	7.02E+02	3.18E+03	5.92E+02	5.58E+02
	EXT AIR	1.45E+05	1.31E+05	4.85E+04	3.60E+04	1.15E+04	1.01E+05	5.38E+04	9.54E+04	3.40E+04	1.31E+05
	EXT GND	8.73E+03	7.87E+03	2.91E+03	2.16E+03	6.90E+02	6.04E+03	3.23E+03	5.73E+03	2.04E+03	7.88E+03

TABLE B-1 (continued):
Dosimetry factors

NUCLIDE	PATHWAY	ORGAN									
		BONE	RED MARROW	LUNG	LIVER	GI-LLI	THYROID	KIDNEY	OTHER ORGAN	OVARIES	TESTES
CS-135	INHAL1	7.47E+03	7.47E+03	6.40E+02	7.47E+03	8.51E+01	7.48E+03	7.47E+03	4.40E+03	7.47E+03	7.47E+03
	INHAL2	7.47E+03	7.47E+03	6.40E+02	7.47E+03	8.51E+01	7.48E+03	7.47E+03	4.40E+03	7.47E+03	7.47E+03
	INGEST	1.12E+04	1.12E+04	0.00E-01	1.12E+04	5.35E+02	1.13E+04	1.12E+04	6.61E+03	1.12E+04	1.12E+04
	EXT AIR	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
	EXT GND	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
CS-137	INHAL1	4.54E+04	4.91E+04	1.62E+04	5.23E+04	1.60E+04	4.47E+04	5.13E+04	3.26E+04	5.00E+04	4.44E+04
	INHAL2	4.54E+04	4.91E+04	1.62E+04	5.23E+04	1.60E+04	4.47E+04	5.13E+04	3.26E+04	5.00E+04	4.44E+04
	INGEST	6.82E+04	7.38E+04	1.99E+04	7.87E+04	2.59E+04	6.72E+04	7.73E+04	4.91E+04	7.54E+04	6.68E+04
	EXT AIR	4.66E+06	4.45E+06	3.60E+06	3.18E+06	2.75E+06	4.02E+06	3.38E+06	3.81E+06	1.39E+06	4.24E+06
	EXT GND	8.29E+04	7.92E+04	6.40E+04	5.65E+04	4.90E+04	7.15E+04	6.03E+04	6.79E+04	2.49E+04	7.55E+04
SM-151	INHAL1	5.10E+02	2.09E+02	6.78E+04	1.90E+03	3.04E+03	1.92E+01	5.54E+02	1.09E+03	1.47E+01	1.07E+01
	INHAL2	4.91E+03	1.94E+03	1.59E+04	1.89E+04	2.81E+03	1.04E+02	5.38E+03	1.19E+03	1.09E+02	1.03E+02
	INGEST	4.91E+00	3.20E+00	1.05E-01	1.73E+01	5.85E+03	1.03E-01	5.52E+00	2.34E+01	5.66E+00	5.36E-01
	EXT AIR	2.44E+01	2.13E+01	4.24E+00	2.35E+00	2.92E+00	9.06E+00	7.02E+00	3.07E+01	3.92E+00	3.88E+01
	EXT GND	4.59E+00	4.00E+00	7.96E-01	4.41E-01	5.48E-01	1.70E+00	1.32E+00	5.78E+00	7.36E-01	7.30E+00
RA-226	INHAL1	1.10E+07	9.80E+05	2.81E+07	3.40E+05	1.00E+05	3.40E+05	3.49E+05	4.60E+06	3.40E+05	3.40E+05
	INHAL2	1.10E+07	9.80E+05	2.81E+07	3.40E+05	1.00E+05	3.40E+05	3.49E+05	4.60E+06	3.40E+05	3.40E+05
	INGEST	6.32E+07	2.14E+06	2.71E+02	1.87E+06	8.16E+05	8.01E+05	5.79E+06	7.79E+06	8.06E+05	8.01E+05
	EXT AIR	1.50E+07	1.39E+07	1.27E+07	1.12E+07	1.03E+07	1.28E+07	1.06E+07	1.18E+07	9.90E+06	1.13E+07
	EXT GND	2.52E+05	2.34E+05	2.07E+05	1.85E+05	1.69E+05	2.12E+05	1.75E+05	2.21E+05	1.63E+05	1.89E+05
U-234	INHAL1	2.00E+07	8.10E+05	2.73E+08	5.90E+05	5.48E+04	5.90E+05	8.70E+05	9.80E+06	5.90E+05	5.90E+05
	INHAL2	5.90E+07	2.40E+06	2.80E+07	1.70E+06	4.79E+04	1.70E+06	2.50E+06	5.50E+06	1.70E+06	1.70E+06
	INGEST	2.00E+07	8.00E+05	8.23E+02	5.80E+05	8.86E+04	5.80E+05	8.50E+05	1.70E+06	5.80E+05	5.80E+05
	EXT AIR	2.94E+03	2.64E+03	1.03E+03	7.64E+02	8.56E+02	1.28E+03	8.13E+02	2.49E+03	6.64E+02	2.09E+03
	EXT GND	5.63E+02	5.05E+02	1.97E+02	1.46E+02	1.64E+02	2.46E+02	1.56E+02	4.78E+02	1.27E+02	4.00E+02
NP-237	INHAL1	9.04E+08	3.01E+08	2.90E+08	4.02E+08	1.38E+05	3.00E+06	5.20E+07	8.50E+07	1.80E+06	5.80E+06
	INHAL2	2.24E+09	7.47E+08	3.00E+07	9.91E+08	1.26E+05	7.40E+06	1.28E+08	1.90E+08	4.60E+06	1.40E+07
	INGEST	1.90E+07	6.20E+06	8.87E+02	8.20E+06	1.46E+05	6.08E+04	1.10E+06	1.60E+06	3.90E+04	1.20E+05
	EXT AIR	3.27E+06	3.03E+06	1.79E+06	1.56E+06	1.13E+06	2.15E+06	1.50E+06	2.05E+06	1.02E+06	2.41E+06
	EXT GND	7.25E+04	6.72E+04	3.97E+04	3.46E+04	2.50E+04	4.47E+04	3.34E+04	4.57E+04	2.27E+04	5.35E+04
PU-238	INHAL1	7.91E+08	2.64E+08	3.09E+08	3.55E+08	6.20E+04	2.60E+06	4.60E+07	7.60E+07	1.60E+06	5.00E+06
	INHAL2	2.03E+09	6.77E+08	3.20E+07	9.07E+08	5.51E+04	6.60E+06	1.17E+08	1.73E+08	4.10E+06	1.30E+07
	INGEST	5.00E+05	1.70E+05	7.89E-02	2.20E+05	1.10E+05	1.64E+03	2.91E+04	4.32E+04	1.03E+03	3.20E+03
	EXT AIR	1.26E+03	1.09E+03	3.02E+02	1.33E+02	4.45E+02	2.46E+02	1.77E+02	1.66E+03	1.86E+02	1.32E+03
	EXT GND	2.47E+02	2.14E+02	5.92E+01	2.60E+01	8.71E+01	4.81E+01	3.46E+01	3.25E+02	3.64E+01	2.58E+02

TABLE B-1 (continued):
Dosimetry factors

NUCLIDE	PATHWAY	ORGAN									
		BONE	RED MARROW	LUNG	LIVER	GI-LLI	THYROID	KIDNEY	OTHER ORGAN	OVARIES	TESTES
PU-239	INHAL1	9.12E+08	3.04E+08	2.94E+08	4.04E+08	5.78E+04	3.00E+06	5.20E+07	8.60E+07	1.80E+06	5.80E+06
	INHAL2	2.28E+09	7.61E+08	3.00E+07	1.00E+09	5.13E+04	7.40E+06	1.30E+08	1.92E+08	4.60E+06	1.50E+07
	INGEST	5.70E+05	1.90E+05	6.09E-02	2.50E+05	9.86E+04	1.85E+03	3.22E+04	4.82E+04	1.15E+03	3.60E+03
	EXT AIR	6.41E+02	5.61E+02	1.71E+02	9.38E+01	1.90E+02	1.89E+02	1.23E+02	7.22E+02	1.17E+02	6.11E+02
	EXT GND	1.22E+02	1.07E+02	3.24E+01	1.78E+01	3.60E+01	3.59E+01	2.33E+01	1.37E+02	2.21E+01	1.16E+02
PU-240	INHAL1	9.13E+08	3.04E+08	2.95E+08	4.05E+08	5.82E+04	3.00E+06	5.20E+07	8.60E+07	1.80E+06	5.80E+06
	INHAL2	2.28E+09	7.60E+08	3.10E+07	1.01E+09	5.17E+04	7.40E+06	1.30E+08	1.94E+08	4.60E+06	1.50E+07
	INGEST	5.70E+05	1.90E+05	8.32E-02	2.50E+05	9.93E+04	1.84E+03	3.22E+04	4.83E+04	1.15E+03	3.60E+03
	EXT AIR	1.16E+03	1.00E+03	2.89E+02	1.40E+02	3.99E+02	2.53E+02	1.78E+02	1.46E+03	1.80E+02	1.17E+03
	EXT GND	2.25E+02	1.96E+02	5.64E+01	2.72E+01	7.79E+01	4.93E+01	3.47E+01	2.85E+02	3.52E+01	2.28E+02
AM-241	INHAL1	9.43E+08	3.14E+08	3.13E+08	4.19E+08	6.52E+04	3.10E+06	5.40E+07	8.90E+07	1.90E+06	6.00E+06
	INHAL2	2.35E+09	7.83E+08	3.20E+07	1.04E+09	6.11E+04	7.70E+06	1.34E+08	1.99E+08	4.80E+06	1.50E+07
	INGEST	1.90E+07	6.40E+06	1.27E+02	8.50E+06	1.10E+05	6.32E+04	1.10E+06	1.60E+06	3.94E+04	1.20E+05
	EXT AIR	2.72E+05	2.48E+05	1.01E+05	8.30E+04	5.68E+04	1.38E+05	8.80E+04	1.44E+05	8.51E+04	1.26E+05
	EXT GND	1.42E+04	1.30E+04	5.30E+03	4.33E+03	2.96E+03	7.21E+03	4.59E+03	7.50E+03	4.44E+03	6.57E+03
PU-242	INHAL1	8.69E+08	2.89E+08	2.80E+08	3.85E+08	5.51E+04	2.80E+06	5.00E+07	8.20E+07	1.80E+06	5.50E+06
	INHAL2	2.17E+09	7.22E+08	2.90E+07	9.56E+08	4.90E+04	7.10E+06	1.23E+08	1.84E+08	4.40E+06	1.40E+07
	INGEST	5.40E+05	1.80E+05	1.60E-01	2.40E+05	9.40E+04	1.76E+03	3.06E+04	4.60E+04	1.09E+03	3.42E+03
	EXT AIR	1.04E+03	8.93E+02	2.36E+02	9.37E+01	3.65E+02	1.77E+02	1.32E+02	1.39E+03	1.51E+02	1.10E+03
	EXT GND	2.03E+02	1.75E+02	4.63E+01	1.84E+01	7.16E+01	3.47E+01	2.59E+01	2.72E+02	2.97E+01	2.17E+02
AM-243	INHAL1	9.43E+08	1.56E+09	3.03E+08	4.21E+08	3.22E+05	3.10E+06	5.40E+07	8.90E+07	1.90E+06	6.00E+06
	INHAL2	2.34E+09	3.87E+09	3.10E+07	1.04E+09	1.50E+05	7.70E+06	1.34E+08	1.99E+08	4.80E+06	1.50E+07
	INGEST	1.90E+07	3.20E+07	9.64E+02	8.50E+06	1.49E+05	6.34E+04	1.10E+06	1.60E+06	4.07E+04	1.20E+05
	EXT AIR	2.17E+06	2.01E+06	1.06E+06	9.14E+05	6.49E+05	1.33E+06	8.97E+05	1.29E+06	6.76E+05	1.41E+06
	EXT GND	5.29E+04	4.88E+04	2.63E+04	2.26E+04	1.61E+04	3.26E+04	2.21E+04	3.15E+04	1.65E+04	3.48E+04

NOTE: THE DOSIMETRY FACTORS IN THE "OTHER ORGAN" COLUMN ARE FOR WHOLE BODY. THE WHOLE BODY DOSIMETRY FACTORS WERE USED BECAUSE MUSCLE OR OTHER SOFT TISSUE FACTORS WERE NOT AVAILABLE IN MANY CASES. THESE WHOLE BODY DOSIMETRY FACTORS ARE THE SAME AS OR HIGHER THAN FACTORS FOR MUSCLE OR OTHER SOFT TISSUE. THIS ADDS CONSERVATISM TO THE OVERALL ANALYSIS.

TABLE B-2:
Source of dosimetry factors

	DOSE FACTOR CATEGORY				
Nuclide	Inhalation Class Y (1)	Inhalation Class W (2)	Ingestion	External Air Submersion	External Ground Contamination
C-14	NUREG/CR-0150* no class given	NUREG/CR-0150* no class given	NUREG/CR-0150	ORNL-4992	ORNL-4992
Ni-59	ORNL-4992 no class given	ORNL-4992 no class given	ORNL-4992	Assumed 0 Pure β	Assumed 0 Pure β
Sr-90	NUREG/CR-0150 Sr-90 is Y, Y-90 is W	NUREG/CR-0150 Sr-90 is D, Y-90 is W	NUREG/CR-0150 F1 = 0.2	ORNL-4992	ORNL-4992
Zr-93	NUREG/CR-0150 Class Y	NUREG/CR-0150 Class W	Zr-93 NUREG/CR-0150 Nb-93m ORNL-4992	Zr-93 Pure β Nb-93m ORNL-4101	Zr-93 Pure β Nb-93m ORNL-4101
Tc-99	NUREG/CR-0150 Class W	NUREG/CR-0150 Class W	NUREG/CR-0150	ORNL-4992	ORNL-4992
Sn-126	NUREG-0172 no class given	NUREG-0172 no class given	NUREG-0172	ORNL-4101	ORNL-4101
I-129	NUREG/CR-0150 Class D	NUREG/CR-0150 Class D	NUREG/CR-0150	ORNL-4992	ORNL-4992
Cs-135	NUREG/CR-0150 Class D	NUREG/CR-0150 Class D	NUREG/CR-0150	ORNL-4992	ORNL-4992
Cs-137	NUREG/CR-0150 Class D	NUREG/CR-0150 Class D	NUREG/CR-0150	ORNL-4992	ORNL-4992
Sm-151	NUREG/CR-0150 Class Y	NUREG/CR-0150 Class W	NUREG/CR-0150	ORNL-4992	ORNL-4992

* Factors taken from page 88 since an error was found for C-14 in the summary tables.

TABLE B-2 (continued):
Source of dosimetry factors

	DOSE FACTOR CATEGORY				
Nuclide	Inhalation Class Y	Inhalation Class W	Ingestion	External Air Submersion	External Ground Contamination
Ra-226	ORNL - Draft Class W	ORNL - Draft Class W	ORNL - Draft	ORNL-4992	ORNL-4992
U-234	ORNL - Draft Class Y	ORNL - Draft Class W	ORNL - Draft	ORNL-4992	ORNL-4992
Np-237	ORNL - Draft Class Y	ORNL - Draft Class W	ORNL - Draft	ORNL-4992	ORNL-4992
Pu-238	ORNL - Draft Class Y	ORNL - Draft Class W	ORNL - Draft	ORNL-4992	ORNL-4992
Pu-239	ORNL - Draft Class Y	ORNL - Draft Class W	ORNL - Draft	ORNL-4992	ORNL-4992
Pu-240	ORNL - Draft Class Y	ORNL - Draft Class W	ORNL - Draft	ORNL-4992	ORNL-4992
Am-241	ORNL - Draft Class Y	ORNL - Draft Class W	ORNL - Draft	ORNL-4992	ORNL-4992
Pu-242	ORNL - Draft Class Y	ORNL - Draft Class W	ORNL - Draft	ORNL-4992	ORNL-4992
Am-243	ORNL - Draft Class Y	ORNL - Draft Class W	ORNL - Draft	ORNL-4992	ORNL-4992

APPENDIX C: SAMPLE DERIVATION OF AN ENVIRONMENTAL PATHWAY EQUATION AND CALCULATION OF POPULATION HEALTH EFFECTS

A derivation of an environmental dose commitment equation and the application of representative data in the equation to compute population health effects for an environmental pathway will serve to illustrate the application of the methodology described in this report. The environmental pathway chosen for demonstration is ingestion of food crops for radionuclide releases to a river (pathway number 3). Terms that are explained in the "Nomenclature" section are not defined again in this Appendix.

An expression for environmental dose commitment must be derived for use in obtaining population health risk estimates. The procedure for generating an equation for environmental dose commitment is the same as is described in section 3.1.4. The starting point is the annual dose to an individual.

The annual dose is given by the concentration of radionuclides in the river water (Q'_{np}/R), the irrigation rate (W), a conversion factor to express the radionuclide intake by an individual per unit deposition to the ground surface (RI_{np}), and the dose conversion factor (D_{nop}) as

$$DI'_{nop} = \frac{Q'_{np}\ W\ RI_{np}\ D_{nop}}{R} \quad . \qquad \text{(C-1)}$$

The annual population dose can be expressed as the individual dose multiplied by the number of persons being fed a particular food crop raised on irrigated land. The number of persons fed can be determined using an estimate of the number of persons who can be fed by raising the food crop on a unit area of land (CP_p), the area of land irrigated (A), and a weighting factor to express the fraction of irrigated land used for a particular crop (f_p) as

$$P_{Fp} = CP_p \, A \, f_p \quad . \qquad \text{(C-2)}$$

Then the annual population dose is

$$S'_{nop} = DI'_{nop} \, P_{Fp} = \frac{Q'_{np} \, W \, RI_{np} \, D_{nop} \, CP_p \, A \, f_p}{R} \quad . \qquad \text{(C-3)}$$

By integrating this expression over time, we obtain an equation for environmental dose commitment as

$$S_{nop} = \frac{Q_{np} \, W \, RI_{np} \, D_{nop} \, CP_p \, A \, f_p}{R} \quad . \qquad \text{(C-4)}$$

Some rearrangement of terms is desirable in equation C-4 since it is to be used for generic rather than site specific analyses. We can write the relationship

$$W \, A = f_R \, R \qquad \text{(C-5)}$$

which yields

$$\frac{W}{R} = \frac{f_R}{A} \quad . \qquad \text{(C-6)}$$

If equation C-6 is substituted into equation C-4, we obtain

$$S_{nop} = Q_{np} \, f_R \, f_p \, RI_{np} \, CP_p \, D_{nop} \quad . \qquad \text{(C-7)}$$

Implicit in equation C-7 is the assumption that all river water used for irrigation contains radionuclides and, consequently, that all land irrigated by river water receives radionuclides released from the waste repository. The methods for obtaining several of the terms included in equation C-7 are discussed below.

Values of RI_{np} were determined using the AIRDOS-EPA computer code (Mo79). Using the nomenclature of the AIRDOS-EPA document, we can express RI_{np} using the rate of consumption of vegetation by a human (U_v), the concentration of radionuclides in the vegetation (C_n^v), and the deposition rate of radionuclides to the ground (d_n) as

$$RI_{np} = \frac{U^v \, C_n^v}{d_n} \qquad \text{(C-8)}$$

where

U^v = quantity of vegetation consumed by a human receptor per unit time (kg/yr),

C_n^v = concentration of nuclide n in and on vegetation (Ci/kg),

d_n = the deposition rate of nuclide n onto the ground (Ci/m^2-yr).

Note that the dimensions for RI_{np} from equation C-8 are Ci intake/yr per Ci deposited/m^2-yr whereas the dimensions we desire are Ci intake over all time per Ci deposited (total)/m^2. It can be shown that the ratio of the equilibrium intake rate to a continuous deposition rate (Ci intake/yr per Ci deposited/m^2-yr) is numerically equal to the ratio of the total integrated intake to the acute surface deposition (Ci intake per Ci deposited/m^2). Thus, if we apply equation C-8 for equilibrium conditions (long buildup times), it is appropriate to use the equation to compute values of RI_{np} for our analysis. The expression for C_n^v is basically the same expression as given in equation 49, page 40, of AIRDOS-EPA (Mo79) modified to account for removal of radionuclides from the plant root zone to a soil sink. The equation is

$$C_n^v = d_n \left[\frac{DDI \; f_c \left[1 - e^{-\lambda_{En} t_{ev}} \right]}{Y_v \, \lambda_{En}} + \frac{B_{iv} \left[1 - e^{-(\lambda_{Dn} + \lambda_{Sn}) t_b} \right]}{P \left(\lambda_{Dn} + \lambda_{Sn} \right)} \right] e^{-\lambda_{Dn} t_{hv}}$$

(C-9)

where

DDI = fraction of nuclide retained on plant foliage which remains after washing (dimensionless),

f_c = fraction of deposited nuclide retained on edible portions of crops (dimensionless),

λ_{En} = the effective removal rate constant for nuclide n from crops (yr^{-1}),

t_{ev} = time period that crops are exposed to contamination during growing season (yr),

Y_v = agricultural productivity (yield) of the edible portion of vegatation (kg/square meter),

B_{iv} = the concentration factor for uptake of radionuclide i from soil by edible parts of crops (Ci/kg plant per Ci/kg dry soil),

λ_{Sn} = removal rate constant for transfer of nuclide n from the root zone to the soil below the root zone (yr^{-1}),

t_b = period of long-term buildup of activity in soil (yr),

P = effective density of the root zone (top 15 cm of soil) (kg dry soil/square meter), and

t_{hv} = a holdup time that represents the time interval between harvest and consumption of the vegetation (yr).

An implicit assumption in equation C-9 is that irrigation water deposits radionuclides on the ground surface continuously. This is a conservative assumption since irrigation would actually take place for less than the full year.

As mentioned above, a significant change was made in equation C-9 that is not included in the models in AIRDOS-EPA. The loss of radionuclides from the soil root zone due to leaching of radionuclides to the soil below the root zone was accounted for by adding the λ_{Sn} term to the equation. This loss mechanism can be important for long-lived radionuclides and this is the reason for including the modification in eqation C-9. The addition of this loss mechanism causes the majority of the total intake of radionuclides from deposition on crop land to occur over a shorter time period after deposition of radioactivity in the environment than would be the case if radioactive decay were the only mechanism for removal from the soil root zone. Substituting equation C-9 into C-8 yields

$$RI_{np} = U^{v} \left[\frac{DDI\ f_c\ [\ 1 - e^{-\lambda_{En} t_{ev}}\ ]}{Y_v\ \lambda_{En}} + \frac{B_{iv}\ [\ 1 - e^{-(\lambda_{Dn} + \lambda_{Sn}) t_b}\ ]}{P\ (\lambda_{Dn} + \lambda_{Sn})} \right] e^{-\lambda_{Dn} t_{hv}} . \tag{C-10}$$

A value is needed for the parameter CP_p for use in equation C-7. CP_p is merely the annual agricultural productivity divided by the annual individual consumption rate of food crops:

$$CP_p = Y_v\ /\ U^{v}\ . \tag{C-11}$$

A leaching-rate-limited source-term equation will be used for this illustrative calculation. Figure C-1 shows the predicted travel of radionuclides from the waste repository to the river. An expression for the rate of entry of radionuclide n to the river can be developed after examination of Figure C-1. The inventory of material at time, t_{er}, when leaching begins is

$$Q_{rnp}(t_{er}) = Q_{on}\ e^{-\lambda_{Dn} t_{er}} \tag{C-12}$$

where

$Q_{rnp}(t_{er})$ = inventory of radionuclide n in the repository at the time leaching begins (Ci) .

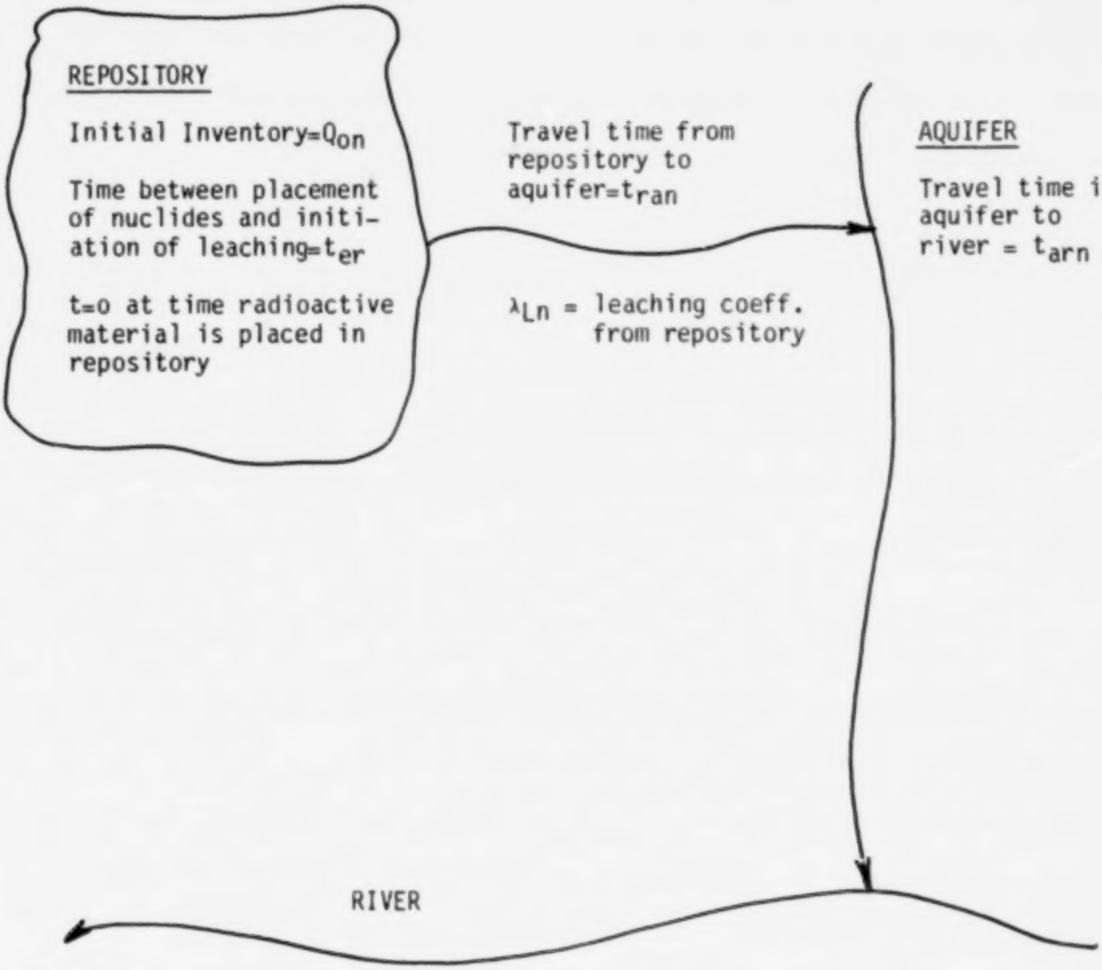
REPOSITORY
Initial Inventory=Q_{on}
Time between placement of nuclides and initiation of leaching=t_{er}
t=o at time radioactive material is placed in repository
Travel time from repository to aquifer=t_{ran}
λ_{Ln} = leaching coeff. from repository
AQUIFER
Travel time in aquifer to river = t_{arn}
RIVER

Fig. C-1. Radionuclide travel from repository to river

At any time t_1 ($t_1 \geq t_{er}$) the rate of exit of radionuclide n from the repository is

$$Q'_{rnp}(t_1) = \lambda_{Ln}\, Q_{rnp}(t_{er})\, e^{-(\lambda_{Dn}+\lambda_{Ln})(t_1-t_{er})} \tag{C-13}$$

where

$Q'_{rnp}(t_1)$ = rate of exit of radionuclide n from the repository at time t_1 (where $t_1 \geq t_{er}$) (Ci/yr) .

Now, assuming that radioactive decay is the only mechanism of loss of radionuclide n during travel from the repository to the aquifer (t_{ran}) and travel from the aquifer to the river (t_{arn}) the equation for release rate to the river at any time t is

$$Q'_{np}(t) = Q'_{rnp}(t_1)\, e^{-\lambda_{Dn}(t_{ran}+t_{arn})} \tag{C-14}$$

$$\text{for} \quad t > t_{er} + t_{ran} + t_{arn}$$

and

$$Q'_{np}(t) = 0 \qquad \text{for } t \leq t_{er} + t_{ran} + t_{arn} \, .$$

The relationship between t and t_1 is

$$t = t_1 + t_{ran} + t_{arn} \tag{C-15}$$

or

$$t_1 = t - t_{ran} - t_{arn} \, . \tag{C-16}$$

Substituting equations C-11 and C-12 into equation C-13 yields

$$Q'_{np}(t) = \lambda_{Ln}\, Q_{on}\, e^{-\lambda_{Dn}t_{er}}\; e^{-(\lambda_{Dn}+\lambda_{Ln})(t_1-t_{er})}\; e^{-\lambda_{Dn}(t_{ran}+t_{arn})} \tag{C-17}$$

or

$$Q'_{np}(t) = \lambda_{Ln}\, Q_{on}\, e^{-\lambda_{Dn}(t_{er}+t_{ran}+t_{arn})}\; e^{-(\lambda_{Dn}+\lambda_{Ln})(t_1-t_{er})} \tag{C-18}$$

and substituting equation C-16 into C-18 gives

$$Q'_{np}(t) = \lambda_{Ln}\, Q_{on}\, e^{-\lambda_{Dn}(t_{er}+t_{ran}+t_{arn})}\; e^{-(\lambda_{Dn}+\lambda_{Ln})(t-t_{ran}-t_{arn}-t_{er})} \qquad \text{(C-19)}$$

or

$$Q'_{np}(t) = \lambda_{Ln}\, Q_{on}\, e^{-\lambda_{Dn}t}\; e^{-\lambda_{Ln}(t-t_{er}-t_{ran}-t_{arn})} \; . \qquad \text{(C-20)}$$

Now, assuming that only a fraction, f_L, of the contents of the repository are subject to leaching, we can write the final expression for the release rate of radionuclide n to the river as

$$Q'_{np}(t) = \lambda_{Ln}\, f_L\, Q_{on}\, e^{-\lambda_{Dn}t}\; e^{-\lambda_{Ln}(t-t_{er}-t_{ran}-t_{arn})} \qquad \text{for } t > t_{er}+t_{ran}+t_{arn}$$

and

$$Q'_{np}(t) = 0 \qquad \text{for } t \leq t_{er}+t_{ran}+t_{arn} \; . \qquad \text{(C-21)}$$

To obtain the total (integrated) amount of radionuclide n that has entered the river up to time t, we integrate equation C-21 and get

$$Q_{np}(t) = \int_{t=o}^{t=t} Q'_{np}(t)dt \; . \qquad \text{(C-22)}$$

Using equation C-21 and the relationship

$$t_{Rn} = t_{er} + t_{ran} + t_{arn} \qquad \text{(C-23)}$$

we obtain

$$Q_{np}(t) = \frac{Q_{on}\, f_L\, \lambda_{Ln}}{(\lambda_{Dn}+\lambda_{Ln})} \left[e^{-\lambda_{Dn}t_{Rn}} - e^{\lambda_{Ln}t_{Rn}}\, e^{-(\lambda_{Dn}+\lambda_{Ln})t} \right] \qquad \text{for } t > t_{Rn} \; .$$

and

$$Q_{np}(t) = 0 \qquad \text{for } t \leq t_{Rn} \; . \qquad \text{(C-24)}$$

Equations C-10, C-11, and C-24 may be used in conjunction with equation C-7 to work out a sample calculation for the environmental dose commitment for human consumption of food crops. Parameter values from sections 4 and 5 will be used in the sample calculations. For variables not discussed in sections 4 and 5, representative values for parameters will be used. The calculations will be done for Tc-99.

To determine the total release of Tc-99 we will use the following data:

Q_{on} = 1000 curies of Tc-99

f_L = 0.01

λ_{Ln} = 1.45 E-4 yr^{-1}

λ_{Dn} = 3.27 E-6 yr^{-1}

t_{er} = 100 yrs

t_{ran} = 1 yr

t_{arn} = 760 R_n yrs, where R_n = 1 (Li77c), therefore:

t_{arn} = 760 (1) = 760 yrs.

Now, from equation C-23

$$t_{Rn} = t_{er} + t_{ran} + t_{arn} = 100 + 1 + 760 = 861 \text{ yrs.}$$

Let the time, t, for computation of the health effects commitment be t = 10,000 yrs. Then, using equation C-24 we have

$$Q_{np}(t) = \frac{\lambda_{Ln}\, f_L\, Q_{on}}{\lambda_{Dn} + \lambda_{Ln}} \left[e^{-\lambda_{Dn} t_{Rn}} - e^{\lambda_{Ln} t_{Rn}}\, e^{-(\lambda_{Dn}+\lambda_{Ln})\, t} \right]$$

and

$$Q(10000) = \frac{(1.45E-4)(0.01)(1000)}{(3.27E-6)+(1.45E-4)} \left\{ e^{-(3.27E-6)(861)} - e^{[(1.45E-4)(861)-(3.27E-6+1.45E-4)(10,000)]} \right\}$$

$$Q(10,000) = (9.779)\ (0.997 - 0.257)$$

Q(10,000) = 7.24 curies of Tc-99 released over 10,000 yrs.

To compute a value for RI_{np}, we need the following data. Except as noted, the reference for this data is AIRDOS-EPA (Mo79).

U^v = 194 kg/yr DDI = 1.0

f_c = 0.2

$\lambda_{En} = \lambda_{Dn} + \lambda_w = 3.26\text{ E-6 yr}^{-1} + 18.41\text{ yr}^{-1} = 18.41\text{ yr}^{-1}$, where

λ_w = time constant for loss from vegatation due to weathering, yr^{-1}.

t_{ev} = 0.164 yrs $Y_v = 0.716\text{ kg/m}^2$

$B_{iv} = 5 \dfrac{\text{Ci/kg crop}}{\text{Ci/kg dry soil}}$ (Ho80)

$\lambda_{Dn} = 3.26\text{ E-6 y}^{-1}$ $\lambda_{Sn} = 1.26\text{ yr}^{-1}$ (Ho80, Ho82)

t_b = 1 E15 yrs* $P = 215\text{ kg dry soil/m}^2$

t_{hv} = 3.83 E-2 yr.

Using these values, the value of RI_{np} can be computed as

$$RI_{np} = 194 \left\{ \frac{(1)(0.2)[1-\exp[(-18.41)(0.164)]]}{(.716)(18.41)} + \frac{(5)[1-\exp[(-3.26\text{ E-6} -1.26)(1\text{E}15)]]}{(215)(3.26\text{ E-6} +1.26)} \right\} \exp[(-3.26\text{ E-6})(3.83\text{ E-2})]$$

$$RI_{np} = 194\ [\ (1.443\text{ E-2}) + (1.846\text{ E-2})\ ]\ 1.0$$

$$RI_{np} = 6.38\ \frac{\text{Ci intake}}{\text{Ci/m}^2\text{ deposited}}\ .$$

The remaining parameter values for use in equation C-7 to compute environmental dose commitment are

$f_R = 0.5$ $f_p = 0.5$ $CP_p = 1\text{ E-3 man/m}^2$.

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*The large value of t_b is used to assure that an equilibrium value for RI_{np} is computed.

The expression for computation of environmental dose commitment is equation C-7, i.e.

$$S_{nop} = Q_{np}\ f_R\ f_p\ RI_{np}\ CP_p\ D_{nop}\ . \qquad \text{(C-7)}$$

Substituting the parameter values discussed above into equation C-7 yields

$$S_{nop} = (7.24)(0.5)(0.5)(6.38)(0.001)\ D_{nop} = 1.155\ \text{E-2}\ D_{nop}.$$

The estimated fatal cancers are computed using the calculated environmental dose commitments (S_{nop}) and fatal cancer conversion factors as

$$FHE_{np} = \sum_{o=1}^{8} S_{nop}\ HECON_o \qquad \text{(C-25)}$$

where

FHE_{np} = the estimated fatal cancers in the population for nuclide n and pathway p.

Since the environmental dose commitments must be computed for eight organs the remaining computations will be tabulated in table C-1. The genetic effects are computed in a similar manner from calculated environmental dose commitments to the gonads; however, this calculation is not included in this appendix.

TABLE C-1:
Environmental dose commitment and fatal cancer calculations

Organ	Dose Commitment Factor, D_{nop} (rem/Ci intake)	Environmental Dose Commitment, S_{nop} (person rem)	Fatal Cancer Conversion Factor, $HECON_o$ (HE/person rem)	Fatal Cancers Committed, FHE_{np}
Bone	3.61 E+2	4.17	1 E-5	4.17 E-5
Red Marrow	3.22 E+2	3.72	4 E-5	1.49 E-4
Lung	0	0	4 E-5	0
Liver	6.28 E+2	7.25	1 E-5	7.25 E-5
GI-LLI Wall	3.20 E+3	37.0	2 E-5	7.39 E-4
Thyroid	1.41 E+4	162.9	1 E-6	1.63 E-4
Kidney	4.58 E+2	5.29	1 E-5	5.29 E-5
Other Soft Tissue	2.14 E+2	2.47	7 E-5	1.73 E-4
			TOTAL	1.39 E-3 Fatal Cancers

Thus, for 7.24 Ci of Tc-99 released to the river, the number of fatal cancers in 10,000 yrs to the affected population from consumption of food crops irrigated by contaminated river water is estimated to be 0.00139. The fatal cancers per curie released for this sample calculation are 0.0014/7.24 = 1.92 E-4. The fatal cancers per curie release for the other nuclides and pathways discussed in this report are determined in a similar manner and are presented in Appendix D.

APPENDIX D: HEALTH EFFECTS PER CURIE RELEASE PARAMETERS

This Appendix displays the various parameters for fatal cancers per curie release that have been calculated using this methodology. These parameters have been used to develop the radionuclide release limits in EPA's proposed environmental standards for high-level and transuranic radioactive waste disposal (EPA82). Parameters for each of the four release modes, for each radionuclide, are shown in Table D-1. Tables D-2, D-3, and D-4 show the contributions of the various environmental pathways to the fatal cancers per curie parameters for the river, ocean, and land surface release modes. All of these parameters were calculated using the input data discussed in Sections 4 and 5 of this report and specific values for the following parameters:

$\lambda_{Ln} = 10^{-4}\ yr^{-1}$

$t_{Rn} = t_{er} + t_{ran} + t_{arn} = 0$*

$t = 10{,}000\ yr$

$f_{LL} = 0.50$

$f_{AL} = 0.15$

$f_{AW} = 0.35$

Specifically note that a period of 10,000 years was used for the integration time. A value of 10^{-4} parts per year was used for the waste leach rate (λ_{Ln}), although these fatal cancers per curie parameters have only a very slight dependence on the value chosen for λ_{Ln}.

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*Setting t_{RN} equal to zero is permissible for these calculations since we are computing the health effects per curie released to the environment. Appropriate non-zero values for t_{er}, t_{ran}, and t_{arn} must be selected when computing the total release quantity of radionuclides from a repository.

TABLE D-1:
Fatal cancers per curie released for different release modes

Nuclide	Releases to a River	Releases to an Ocean	Releases to Land Surface	Releases due to Violent Interactions*
C-14	4.58 E- 2	1.12 E- 7	2.58 E- 5	7.65 E- 2
Ni-59	6.80 E- 4	6.74 E- 5	1.10 E- 5	1.23 E- 4
Sr-90	1.21 E- 1	1.91 E- 6	9.75 E- 4	1.63 E- 2
Zr-93	6.94 E- 2	5.74 E- 6	1.82 E- 1	1.55 E- 1
Tc-99	2.85 E- 4	1.04 E- 6	6.03 E- 8	3.67 E- 5
Sn-126	1.20 E- 1	7.86 E- 6	4.13 E- 2	1.12 E- 1
I-129	1.08 E- 2	9.62 E- 5	2.31 E- 5	1.38 E- 3
Cs-135	3.81 E- 3	1.58 E- 5	4.01 E- 4	7.36 E- 4
Cs-137	1.98 E- 2	1.60 E- 5	5.62 E- 4	6.91 E- 3
Sm-151	1.17 E- 4	1.38 E- 6	2.89 E- 6	1.64 E- 5
Ra-226	3.16	1.49 E- 2	8.42 E- 2	4.87 E- 1
U-234	1.33	1.38 E- 3	5.70 E- 1	6.13 E- 1
Np-237	5.96 E- 1	2.44 E- 3	3.22 E- 3	8.03 E- 2
Pu-238	2.29 E- 2	2.38 E- 5	3.21 E- 3	1.47 E- 2
Pu-239	6.92 E- 2	1.31 E- 4	5.55 E- 2	5.18 E- 2
Pu-240	6.53 E- 2	1.15 E- 4	4.94 E- 2	4.76 E- 2
Am-241	7.19 E- 1	1.19 E- 2	8.98 E- 2	1.59 E- 1
Pu-242	6.76 E- 2	1.30 E- 4	5.63 E- 2	5.13 E- 2
Am-243	2.68 E 0	8.81 E- 2	1.03 E 0	1.14 E 0

---

*For example, interaction of a meteorite or a volcanic eruption with a repository.

TABLE D-2:
Fatal cancers per curie released for releases to a river

Nuclide	TOTAL	Drinking Water Ingestion (p = 1)	Freshwater Fish Ingestion (p = 2)	Above Surface Crops Ingestion (p = 3)	Milk Ingestion (p = 4)	Beef Ingestion (p = 5)	Inhalation of Resuspended Material (p = 6)	External Dose - Ground Contam. (p = 7)	External Dose - Air Submersion (p = 8)
C-14	4.58 E- 2	7.40 E- 5	5.59 E- 4	2.99 E- 2	1.11 E- 2	4.10 E- 3	1.46 E-12	0.0	0.0
Ni-59	6.80 E- 4	8.21 E- 5	1.36 E- 5	4.03 E- 4	9.80 E- 5	8.28 E- 5	1.46 E- 8	0.0	0.0
Sr-90	1.21 E- 1	8.03 E- 3	6.66 E- 5	1.05 E- 1	7.79 E- 3	1.04 E- 4	7.87 E- 7	0.0	0.0
Zr-93	6.94 E- 2	7.79 E- 5	4.30 E- 7	3.01 E- 4	9.39 E- 4	4.24 E- 5	8.15 E- 7	6.81 E- 2	0.0
Tc-99	2.85 E- 4	2.42 E- 5	6.02 E- 7	1.92 E- 4	6.25 E- 5	5.82 E- 6	4.92 E-10	0.0	0.0
Sn-126	1.20 E- 1	1.41 E- 3	7.01 E- 3	6.66 E- 3	2.95 E- 4	2.09 E- 3	3.71 E- 6	1.02 E- 1	5.61 E- 9
I-129	1.08 E- 2	1.63 E- 3	4.05 E- 5	6.43 E- 3	2.44 E- 3	1.84 E- 4	1.22 E- 8	9.19 E- 5	1.54 E-12
Cs-135	3.81 E- 3	2.55 E- 4	1.69 E- 4	2.13 E- 3	9.99 E- 4	2.65 E- 4	1.12 E- 7	0.0	0.0
Cs-137	1.98 E- 2	2.01 E- 3	1.33 E- 3	7.83 E- 3	2.08 E- 3	5.55 E- 4	7.51 E- 8	5.96 E- 3	3.35 E-10
Sm-151	1.17 E- 4	2.39 E- 5	9.92 E- 7	8.99 E- 5	1.77 E- 8	1.87 E- 6	3.22 E- 8	7.50 E- 7	3.98 E-15
Ra-226	3.16	2.73 E- 1	2.26 E- 2	2.78	3.38 E- 2	3.03 E- 3	4.31 E- 5	4.56 E- 2	2.63 E- 9
U-234	1.33	7.39 E- 2	1.23 E- 3	1.25	6.14 E- 3	7.46 E- 6	1.40 E- 3	1.83 E- 3	9.54 E-12
Np-237	5.96 E- 1	1.30 E- 1	2.15 E- 3	4.60 E- 1	9.21 E- 5	3.90 E- 4	4.36 E- 4	2.09 E- 3	9.39 E-11
Pu-238	2.29 E- 2	3.92 E- 3	2.28 E- 3	1.42 E- 2	3.03 E- 8	1.16 E- 9	2.40 E- 3	5.16 E- 5	2.63 E-13
Pu-239	6.92 E- 2	4.32 E- 3	2.50 E- 3	2.51 E- 2	5.39 E- 8	2.06 E- 9	3.69 E- 2	3.24 E- 4	1.71 E-12
Pu-240	6.53 E- 2	4.32 E- 3	2.51 E- 3	2.37 E- 2	5.16 E- 8	1.97 E- 9	3.41 E- 2	5.86 E- 4	3.00 E-12
Am-241	7.19 E- 1	1.32 E- 1	5.47 E- 3	5.61 E- 1	8.32 E- 4	3.91 E- 6	1.14 E- 2	8.61 E- 3	1.64 E-10
Pu-242	6.76 E- 2	4.10 E- 3	2.38 E- 3	2.43 E- 2	4.44 E- 8	4.29 E- 8	3.62 E- 2	6.07 E- 4	3.10 E-12
Am-243	2.68 E 0	3.38 E- 1	1.40 E- 2	2.13 E 0	3.28 E- 3	1.55 E- 5	8.93 E- 2	1.13 E- 1	4.61 E- 9

TABLE D-3:
Fatal cancers per curie released for releases to an ocean

Nuclide	TOTAL	Ocean Fish Ingestion (p = 9)	Ocean Shellfish Ingestion (p = 10)
C-14	1.12 E- 7	9.60 E- 8	1.60 E- 8
Ni-59	6.74 E- 5	6.52 E- 5	2.17 E- 6
Sr-90	1.91 E- 6	1.64 E- 6	2.73 E- 7
Zr-93	5.74 E- 6	3.68 E- 6	2.06 E- 6
Tc-99	1.04 E- 6	3.90 E- 7	6.50 E- 7
Sn-126	7.86 E- 6	6.74 E- 6	1.12 E- 6
I-129	9.62 E- 5	5.25 E- 5	4.37 E- 5
Cs-135	1.58 E- 5	1.24 E- 5	3.43 E- 6
Cs-137	1.60 E- 5	1.25 E- 5	3.47 E- 6
Sm-151	1.38 E- 6	1.80 E- 7	1.20 E- 6
Ra-226	1.49 E- 2	1.12 E- 2	3.72 E- 3
U-234	1.38 E- 3	1.18 E- 3	1.97 E- 4
Np-237	2.44 E- 3	2.09 E- 3	3.47 E- 4
Pu-238	2.38 E- 5	4.13 E- 6	1.97 E- 5
Pu-239	1.31 E- 4	2.27 E- 5	1.08 E- 4
Pu-240	1.15 E- 4	1.99 E- 5	9.51 E- 5
Am-241	1.19 E- 2	1.55 E- 3	1.03 E- 2
Pu-242	1.30 E- 4	2.26 E- 5	1.04 E- 4
Am-243	8.81 E- 2	1.15 E- 2	7.66 E- 2

TABLE D-4:
Fatal cancers per curie released for releases to a land surface

Nuclide	TOTAL	Above Surface Crops Ingestion (p = 13)	Milk Ingestion (p = 14)	Beef Ingestion (p = 15)	Inhalation of Resuspended Material (p = 12)	External Dose - Ground Contam. (p = 16)	External Dose - Air Submersion (p = 11)
C-14	2.58 E- 5	1.74 E- 5	6.17 E- 6	2.28 E- 6	2.92 E-12	0.0	0.0
Ni-59	1.10 E- 5	7.63 E- 6	1.77 E- 6	1.50 E- 6	2.96 E- 8	0.0	0.0
Sr-90	9.75 E- 4	9.04 E- 4	6.39 E- 5	8.50 E- 7	6.33 E- 6	0.0	0.0
Zr-93	1.82 E- 1	1.07 E- 4	3.19 E- 4	1.44 E- 5	3.10 E- 6	1.81 E- 1	0.0
Tc-99	6.03 E- 8	4.42 E- 8	1.38 E- 8	1.29 E- 9	9.83 E-10	0.0	0.0
Sn-126	4.13 E- 2	4.02 E- 4	1.70 E- 5	1.21 E- 4	7.56 E- 6	4.07 E- 2	3.42 E- 8
I-129	2.31 E- 5	1.55 E- 5	5.64 E- 6	4.25 E- 7	2.44 E- 8	1.45 E- 6	9.19 E-12
Cs-135	4.01 E- 4	2.56 E- 4	1.15 E- 4	3.04 E- 5	2.31 E- 7	0.0	0.0
Cs-137	5.62 E- 4	8.93 E- 5	2.27 E- 5	6.04 E- 6	1.50 E- 7	4.43 E- 4	2.01 E- 9
Sm-151	2.89 E- 6	2.54 E- 6	4.76 E-10	5.07 E- 8	1.62 E- 7	1.38 E- 7	2.39 E-14
Ra-226	8.42 E- 2	7.51 E- 2	8.75 E- 4	2.81 E- 5	8.62 E- 5	8.05 E- 3	1.58 E- 8
U-234	5.70 E- 1	5.43 E- 1	2.55 E- 3	3.10 E- 6	1.83 E- 2	6.19 E- 3	7.08 E-11
Np-237	3.22 E- 3	2.66 E- 3	5.09 E- 7	2.15 E- 6	4.84 E- 4	7.89 E- 5	5.66 E-10
Pu-238	3.21 E- 3	4.80 E- 4	9.78 E-10	3.74 E-11	2.72 E- 3	1.14 E- 5	1.58 E-12
Pu-239	5.55 E- 2	8.65 E- 3	1.78 E- 8	6.78 E-10	4.60 E- 2	8.18 E- 4	1.16 E-11
Pu-240	4.94 E- 2	7.52 E- 3	1.57 E- 8	5.97 E-10	4.05 E- 2	1.31 E- 3	1.95 E-11
Am-241	8.98 E- 2	7.00 E- 2	9.93 E- 5	4.67 E- 7	1.27 E- 2	6.99 E- 3	9.86 E-10
Pu-242	5.63 E- 2	8.65 E- 3	1.51 E- 8	1.46 E- 8	4.61 E- 2	1.61 E- 3	2.14 E-11
Am-243	1.03 E 0	6.82 E- 1	1.00 E- 3	4.77 E- 6	8.98 E- 2	2.55 E- 1	3.00 E- 8

APPENDIX E: FORTRAN LISTING OF PROGRAM WESPDOSE: WESP POPULATION ENVIRONMENTAL DOSE COMMITMENT CODE

```
C
C  J. M. SMITH
C  EPA/EERF
C  P. O. BOX 3009
C  MONTGOMERY,AL 36193
C
      INTEGER*2 P,O,PDUM,OVARIE,TESTES
      REAL*4 IW,INTAKE,IB
      REAL*8 HEAD1
C
      COMMON/BLK1/HEAD1(2,10),HEAD2(2,12),HEAD3(2),HEAD4(2,5),
     1DIALNU,NN,NWLBOD,NCARB,IPRINT,OVARIE,TESTES,XLABEL(30)
C
      COMMON/BLK2/D(5,10),RI(3),CF(3),WATER(30),
     1POP(30),USEFR(30),GENVAR(30),PD(30),INTAKE(30),
     2F(30),CP(30),FRCARB(30),DOSSUM(10),HEFSUM(12),
     3HEGSUM(12),IP1(30),IP2(30),IP3(30),HECON(10),HE(10),
     4VG,VW,SOF(30),IW,IB
C
      MAXP = 30
      MAXN = 19
      MAXO = 10
      MAXSUM = 12
      MAXP1 = 5
      MAXP2 = 3
      MAXP3 = 3
      READ(5,903)IPRINT,(XLABEL(J),J=1,15)
C
      READ(5,906)NN,NCARB,(HECON(O),O=1,MAXO),(WATER(P),POP(P),
     1USEFR(P),GENVAR(P),PD(P),SOF(P),P=1,MAXP)
C
C
C  WRITE OUT APPROPRIATE INPUT DATA AND HEADINGS.
C
      WRITE(6,909)IPRINT,IW,IB,NN,MAXO,MAXP,MAXSUM,NWLBOD,
     1NCARB,OVARIE,TESTES,(P,WATER(P),POP(P),USEFR(P),GENVAR(P),PD(P),
     2INTAKE(P),F(P),CP(P),FRCARB(P),SOF(P),IP1(P),IP2(P),IP3(P),P,
     3P=1,MAXP),((HEAD1(IDUM,O),IDUM=1,2),O=1,MAXO),(HECON(O),O=1,MAXO)
C
      WRITE(6,912)((HEAD1(IDUM,O),IDUM=1,2),O=1,MAXO)
      WRITE(10,915)(JDUM,JDUM=1,MAXP2),(JDUM,JDUM=1,MAXP3)
      WRITE(11,918)((HEAD1(IDUM,O),IDUM=1,2),O=1,MAXO)
      WRITE(12,921)
      WRITE(12,927)((HEAD2(IDUM,PDUM),IDUM=1,2),PDUM=1,MAXSUM)
      WRITE(13,924)
      WRITE(13,927)((HEAD2(IDUM,PDUM),IDUM=1,2),PDUM=1,MAXSUM)
      WRITE(15,928)(XLABEL(J),J=1,19)
      WRITE(16,928)(XLABEL(J),J=1,19)
      IF(IPRINT.EQ.2)WRITE(14,930)((HEAD1(IDUM,O),IDUM=1,2),O=1,MAXO)
C
```

```
C  INITIATE LOOP TO CYCLE THROUGH NUCLIDES
      DO 100 N=1,NN
      PDUM=1
      READ(5,940)(HEAD3(IDUM),IDUM=1,2),DIALNU,(CF(J),J=1,MAXP2),
     1(RI(J),J=1,MAXP3),VG,VW,((D(J,O),O=1,MAXO),J=1,MAXP1)
C
      WRITE(6,942)(HEAD3(IDUM),IDUM=1,2),((HEAD4(IDUM,J),IDUM=1,2),
     1(D(J,O),O=1,MAXO),J=1,MAXP1)
C
      WRITE(10,944)(HEAD3(IDUM),IDUM=1,2),DIALNU,N,(CF(J),J=1,MAXP2),
     1(RI(J),J=1,MAXP3),VG,VW
C
C  INITIATE LOOP TO CYCLE THROUGH PATHWAYS
C
      DO 70 P=1,MAXP
C
C  INITIATE LOOP TO CYCLE THROUGH ORGANS
C
      HETOT = 0.
      DO 50 O=1,MAXO
C
      DOS=DOSN(N,P,O)
      IF(O.EQ.OVARIE.OR.O.EQ.TESTES)DOS=DOS/2.
      HE(O)=DOS*HECON(O)
      IF ( O .LE. MAXO-2 ) HETOT=HETOT+HE(O)
C
      DOSSUM(O)=DOSSUM(O)+DOS
      IF(O.LE.8)HEFSUM(PDUM)=HEFSUM(PDUM)+HE(O)
      IF(O.GT.8)HEGSUM(PDUM)=HEGSUM(PDUM)+HE(O)
50    CONTINUE
      IF(IPRINT.EQ.2)WRITE(14,950)(HEAD3(IDUM),IDUM=1,2),P,HETOT,
     1(HE(O),O=1,MAXO)
C
      IF(P.NE.5.AND.P.NE.8.AND.P.NE.10.AND.P.NE.12.AND.P.NE.15.AND.P
     1.NE.16.AND.P.NE.21.AND.P.NE.22.AND.P.NE.24.AND.P.NE.27.AND.P.NE.
     228.AND.P.NE.30)GO TO 63
C
      WRITE(11,953)(HEAD3(IDUM),IDUM=1,2),(HEAD2(IDUM,PDUM),IDUM=1,2),
     1(DOSSUM(O),O=1,MAXO)
      DO 60 O=1,MAXO
60    DOSSUM(O)=0.
      PDUM=PDUM+1
63    CONTINUE
70    CONTINUE
C
      WRITE(12,956)(HEAD3(IDUM),IDUM=1,2),(HEFSUM(PDUM),PDUM=1,MAXSUM)
      WRITE(15,959)DIALNU,(HEFSUM(PDUM),PDUM=1,MAXSUM)
      WRITE(13,956)(HEAD3(IDUM),IDUM=1,2),(HEGSUM(PDUM),PDUM=1,MAXSUM)
      WRITE(16,959)DIALNU,(HEGSUM(PDUM),PDUM=1,MAXSUM)
      WRITE(11,963)
      IF(IPRINT.EQ.2)WRITE(14,963)
C
```

```
      DO 90 PDUM=1,MAXSUM
      HEFSUM(PDUM)=0.
90    HEGSUM(PDUM)=0.
C
100   CONTINUE
C
903   FORMAT(I3,15A4)
906   FORMAT(I3,2X,I3/10E10.3/(6E10.3))
909   FORMAT(36X,'WESP ENVIRONMENTAL DOSE COMMITMENT ESTIMATES'///
     155X,'INPUT DATA'///2X,'CALCULATION OPTION(IPRINT)=',I2//2X,'IW=',
     31PE10.3,' L/Y     IB=',1PE10.3,' M**3/Y     NN=',I3,4X,'MAXO=',
     4I3,3X,'MAXP=',I3,3X,'MAXSUM=',I3//2X,'NWLBOD=',I3,5X,'NCARB=',
     4I3,5X,'OVARIE=',I3,5X,'TESTES=',
     5I3///52X,'PATHWAY DEPENDENT INPUT DATA'//2X,'P WATER(P)   POP(P)',
     63X,'USEFR(P) GENVAR(P)   PD(P)   INTAKE(P)    F(P)     CP(P)',
     73X,'FRCARB(P)   SOF(P)   IP1  IP2  IP3   P'/
     776X,'PERSONS'/4X,'L/Y OR L',4X,
     8'MAN',17X,'1/M     MAN/M**2    KG/Y',14X,'FED/M**2'/30(1X,I2,
     910(1PE10.3),3(1X,I3,1X),1X,I3/)///37X,'HEALTH EFFECTS CONVERSION',
     1' FACTORS,  HEALTH EFFECTS/MAN REM'/1X,'(FATAL CANCERS FOR ALL ',
     2'ORGANS EXCEPT OVARIES AND TESTES.  GENETIC EFFECTS TO FIRST',
     3' GENERATION FOR OVARIES AND',
     4' TESTES)'//1X,10(1X,2A5,1X)//10(1X,1PE10.3,1X)///)
912   FORMAT(52X,'NUCLIDE DEPENDENT INPUT DATA'//2X,'NUCLIDE  PATHWAY',
     128X,'DOSE COMMITMENT FACTORS'/1X,'(INHALATION AND INGESTION=',
     2'REM/CI INTAKE    AIR SUBMERSION=REM/Y PER CI/M**3   GROUND',
     3' CONTAMINATION=REM/Y PER CI/M**2)'//55X'ORGAN'//21X,10(2A5))
915   FORMAT(//27X,'**********CF(N,IP2)**********  *********RI(N,IP3)',
     1'**********'/34X,'CI/KG PER CI/L        CI INTAKE PER CI/M**2',
     2' DEPOSITED   VG(N)    VW(N)'/29X,'IP2=',I2,4X,'IP2=',I2,4X,
     3'IP2=',I2,4X,'IP3=',I2,4X,'IP3=',I2,4X,'IP3=',I2,6X,'M/Y',6X,
     4'M/Y'/2X,'NUCLIDE  DIALNU(N)  N'//)
918   FORMAT(/26X,'SMITH FACTORS FOR POPULATION DOSE AS A FUNCTION OF',
     1' NUCLIDE AND ORGAN'//14X,'SUB',46X,'ORGAN'/2X,'NUCLIDE',2X,
     2'PATHWAYS'/12X,'SUMMED',8(1X,2A5),3X,2(1X,2A5)/)
921   FORMAT(/33X,'SMITH FACTORS FOR POPULATION FATAL CANCERS',
     1' AS A FUNCTION OF NUCLIDE'/)
924   FORMAT(22X,'SMITH FACTORS FOR POPULATION GENETIC EFFECTS TO ',
     1'FIRST GENERATION AS A FUNCTION OF NUCLIDE'/)
927   FORMAT(/2X,'NUCLIDE  ********************',
     1'********************************SUBPATHWAYS SUMMED**********',
     2'**************************************'/9X,12(4X,2A3))
928   FORMAT(1H ,30A4)
930   FORMAT(17X,'SMITH FACTORS FOR POPULATION HEALTH EFFECTS AS A',
     1' FUNCTION OF NUCLIDE, SUBPATHWAY, AND ORGAN'//13X,'SUB',47X,
     2'ORGAN',45X,'FIRST GENERATION'/2X,'NUCLIDE  PATHWAY********',
     3'************************',
     4'FATAL CANCERS********************************************     ',
     5'***GENETIC EFFECTS***'/17X,8(1X,2A5),3X,2(1X,2A5)/)
```

```
940   FORMAT(A4,A3,2X,F8.3,3X,8(E10.3)/
     1(10E10.3))
942   FORMAT(/2X,A4,A3,2X,2A4,1X,10(1PE10.3)/(11X,2A4,1X,
     110(1PE10.3)))
944   FORMAT(2X,A4,A3,3X,F8.3,2X,I2,2X,8(1PE10.3))
950   FORMAT(2X,A4,A3,4X,I3,1X,9(1X,1PE9.2),3X,2(1X,1PE9.2))
953   FORMAT(2X,A4,A3,2X,2A3,1X,8(1X,1PE10.3),3X,2(1X,1PE10.3))
956   FORMAT(2X,A4,A3,2X,12(1PE10.3))
959   FORMAT(1H ,F8.3,6(1PE10.3)/1H ,6(1PE10.3))
963   FORMAT(/)
      STOP
      END
C
```

```
      BLOCK DATA
C  THIS SUBPROGRAM CONTAINS ALL DATA STATEMENTS
C
C
C  DATA STATEMENTS
C
      INTEGER*2 P,O,PDUM,OVARIE,TESTES
      REAL*4 IW,INTAKE,IB
      REAL*8 HEAD1
C
      COMMON/BLK1/HEAD1(2,10),HEAD2(2,12),HEAD3(2),HEAD4(2,5),
     1DIALNU,NN,NWLBOD,NCARB,IPRINT,OVARIE,TESTES,XLABEL(30)
C
      COMMON/BLK2/D(5,10),RI(3),CF(3),WATER(30),
     1POP(30),USEFR(30),GENVAR(30),PD(30),INTAKE(30),
     2F(30),CP(30),FRCARB(30),DOSSUM(10),HEFSUM(12),
     3HEGSUM(12),IP1(30),IP2(30),IP3(30),HECON(10),HE(10),
     4VG,VW,SOF(30),IW,IB
C
      DATA HEAD1/'   BO','NE','RED M','ARROW','   LU','NG','  LIV','ER',
     1'  GI-','LLI','  THY','ROID','  KID','NEY','OTHER','ORGAN',
     2' OVAR','IES','  TES','TES'/
      DATA HEAD2/'  1','-5','  6','-8',' 9-','10',' 11','-12',' 13',
     1'-15','  1','6',' 17','-21','  2','2',' 23','-24',' 25','-27',
     2'  2','8','29','-30'/
      DATA HEAD4/' INH','AL1',' INH','AL2',' ING','EST','EXT ','AIR',
     1'EXT ','GND'/
      DATA DOSSUM/10*0./
      DATA HEFSUM/12*0./
      DATA HEGSUM/12*0./
      DATA IP1/3,3,3,3,3,2,5,4,3,3,4,1,3,3,3,5,1,4,3,3,3,5,4,1,3,3,3,
     15,3,3/
      DATA IP2/0,1,0,0,0,0,0,0,2,3,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
     10,2,3/
      DATA IP3/0,0,1,2,3,0,0,0,0,0,0,0,1,2,3,0,0,0,1,2,3,0,0,0,1,2,3,
     10,0,0/
      DATA FRCARB/0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
     1.01,0.,.99,0.,0.,0.,0.,.01,.99,0.,0.,0.,1.,0./
      DATA NWLBOD,OVARIE,TESTES/8,9,10/
      DATA IW,IB/603.,8401./
      DATA F/0.,0.,.50,.25,.25,0.,0.,0.,0.,0.,0.,0.,.23,.11,.11,0.,0.,
     10.,.23,.11,.11,0.,0.,0.,.23,.11,.11,0.,0.,0./
      DATA CP/0.,0.,.001,.0015,.00021,0.,0.,0.,0.,0.,0.,0.,.001,.0015,
     1.00021,0.,0.,0.,.001,.0015,.00021,0.,0.,0.,.001,.0015,.00021,0.,
     20.,0./
      DATA INTAKE/0.,1.,0.,0.,0.,0.,0.,0.,6.,1.,0.,0.,0.,0.,0.,0.,0.,
     10.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,6.,1./
C
      END
C
```

```
      FUNCTION DOSN(N,P,O)
C
C
      INTEGER*2 P,O,PDUM,OVARIE,TESTES
      REAL*4 IW,INTAKE,IB
      REAL*8 HEAD1
C
      COMMON/BLK1/HEAD1(2,10),HEAD2(2,12),HEAD3(2),HEAD4(2,5),
     1DIALNU,NN,NWLBOD,NCARB,IPRINT,OVARIE,TESTES,XLABEL(30)
C
      COMMON/BLK2/D(5,10),RI(3),CF(3),WATER(30),
     1POP(30),USEFR(30),GENVAR(30),PD(30),INTAKE(30),
     2F(30),CP(30),FRCARB(30),DOSSUM(10),HEFSUM(12),
     3HEGSUM(12),IP1(30),IP2(30),IP3(30),HECON(10),HE(10),
     4VG,VW,SOF(30),IW,IB
C
C
C  THIS FUNCTION SUBPROGRAM SELECTS THE PROPER FUNCTION FOR CALCULATING
C  DOSE FOR SUBPATHWAY P.
C
      IF(N.NE.NCARB)GO TO 30
      IF(P.GE.17)GO TO 9
30    GO TO (1,2,3,3,3,4,5,6,2,2,6,4,3,3,3,5,4,6,7,7,7,5,6,4,3,
     13,3,5,8,8),P
C
1     DOSN=DOSNA(P,O)
      GO TO 40
2     DOSN=DOSNB(P,O)
      GO TO 40
3     DOSN=DOSNC(P,O)
      GO TO 40
4     DOSN=DOSND(P,O)
      GO TO 40
5     DOSN=DOSNE(P,O)
      GO TO 40
6     DOSN=DOSNF(P,O)
      GO TO 40
7     DOSN=DOSNG(P,O)
      GO TO 40
8     DOSN=DOSNH(P,O)
      GO TO 40
9     DOSN=DOSNI(P,O)
40    RETURN
      END
C  *************************
C
```

```
      FUNCTION DOSNA(P,O)
C
C
      INTEGER*2 P,O,PDUM,OVARIE,TESTES
      REAL*4 IW,INTAKE,IB
      REAL*8 HEAD1
C
      COMMON/BLK1/HEAD1(2,10),HEAD2(2,12),HEAD3(2),HEAD4(2,5),
     1DIALNU,NN,NWLBOD,NCARB,IPRINT,OVARIE,TESTES,XLABEL(30)
C
      COMMON/BLK2/D(5,10),RI(3),CF(3),WATER(30),
     1POP(30),USEFR(30),GENVAR(30),PD(30),INTAKE(30),
     2F(30),CP(30),FRCARB(30),DOSSUM(10),HEFSUM(12),
     3HEGSUM(12),IP1(30),IP2(30),IP3(30),HECON(10),HE(10),
     4VG,VW,SOF(30),IW,IB
C
C  DRINKING WATER SUBPATHWAY.  P=1
C
C
      DOSNA=POP(P)*IW*D(IP1(P),O)/WATER(P)
C
      RETURN
      END
C  ********************
C
```

```
      FUNCTION DOSNB(P,O)
C
C
      INTEGER*2 P,O,PDUM,OVARIE,TESTES
      REAL*4 IW,INTAKE,IB
      REAL*8 HEAD1
C
      COMMON/BLK1/HEAD1(2,10),HEAD2(2,12),HEAD3(2),HEAD4(2,5),
     1DIALNU,NN,NWLBOD,NCARB,IPRINT,OVARIE,TESTES,XLABEL(30)
C
      COMMON/BLK2/D(5,10),RI(3),CF(3),WATER(30),
     1POP(30),USEFR(30),GENVAR(30),PD(30),INTAKE(30),
     2F(30),CP(30),FRCARB(30),DOSSUM(10),HEFSUM(12),
     3HEGSUM(12),IP1(30),IP2(30),IP3(30),HECON(10),HE(10),
     4VG,VW,SOF(30),IW,IB
C
C  FISH AND SHELLFISH INGESTION.   P=2,9,10
C
C
      DOSNB=CF(IP2(P))*POP(P)*INTAKE(P)*D(IP1(P),O)/WATER(P)
C
      RETURN
      END
C  ********************
C
```

```
      FUNCTION DOSNC(P,O)
C
C
      INTEGER*2 P,O,PDUM,OVARIE,TESTES
      REAL*4 IW,INTAKE,IB
      REAL*8 HEAD1
C
      COMMON/BLK1/HEAD1(2,10),HEAD2(2,12),HEAD3(2),HEAD4(2,5),
     1DIALNU,NN,NWLBOD,NCARB,IPRINT,OVARIE,TESTES,XLABEL(30)
C
      COMMON/BLK2/D(5,10),RI(3),CF(3),WATER(30),
     1POP(30),USEFR(30),GENVAR(30),PD(30),INTAKE(30),
     2F(30),CP(30),FRCARB(30),DOSSUM(10),HEFSUM(12),
     3HEGSUM(12),IP1(30),IP2(30),IP3(30),HECON(10),HE(10),
     4VG,VW,SOF(30),IW,IB
C
C  ABOVE SURFACE CROPS,MILK,BEEF INGESTION.  P=3,4,5,13,14,15,25,26,27
C
C
      DOSNC=USEFR(P)*F(P)*RI(IP3(P))*CP(P)*D(IP1(P),O)
C
      RETURN
      END
C  ********************
C
```

```
      FUNCTION DOSND(P,O)
C
C
      INTEGER*2 P,O,PDUM,OVARIE,TESTES
      REAL*4 IW,INTAKE,IB
      REAL*8 HEAD1
C
      COMMON/BLK1/HEAD1(2,10),HEAD2(2,12),HEAD3(2),HEAD4(2,5),
     1DIALNU,NN,NWLBOD,NCARB,IPRINT,OVARIE,TESTES,XLABEL(30)
C
      COMMON/BLK2/D(5,10),RI(3),CF(3),WATER(30),
     1POP(30),USEFR(30),GENVAR(30),PD(30),INTAKE(30),
     2F(30),CP(30),FRCARB(30),DOSSUM(10),HEFSUM(12),
     3HEGSUM(12),IP1(30),IP2(30),IP3(30),HECON(10),HE(10),
     4VG,VW,SOF(30),IW,IB
C
C   INHALATION OF RESUSPENDED MATERIAL.  P=6,12,17,24
C
C
      DOSND=GENVAR(P)*PD(P)*IB*D(IP1(P),O)*USEFR(P)
C
      RETURN
      END
C   ********************C
```

```
      FUNCTION DOSNE(P,O)
C
C
      INTEGER*2 P,O,PDUM,OVARIE,TESTES
      REAL*4 IW,INTAKE,IB
      REAL*8 HEAD1
C
      COMMON/BLK1/HEAD1(2,10),HEAD2(2,12),HEAD3(2),HEAD4(2,5),
     1DIALNU,NN,NWLBOD,NCARB,IPRINT,OVARIE,TESTES,XLABEL(30)
C
      COMMON/BLK2/D(5,10),RI(3),CF(3),WATER(30),
     1POP(30),USEFR(30),GENVAR(30),PD(30),INTAKE(30),
     2F(30),CP(30),FRCARB(30),DOSSUM(10),HEFSUM(12),
     3HEGSUM(12),IP1(30),IP2(30),IP3(30),HECON(10),HE(10),
     4VG,VW,SOF(30),IW,IB
C
C  EXTERNAL DOSE--GROUND CONTAMINATION.  P=7,16,22,28
C
C
      DOSNE=USEFR(P)*PD(P)*D(IP1(P),O)*SOF(P)
C
      RETURN
      END
C  ********************
C
```

```
      FUNCTION DOSNF(P,O)
C
C
      INTEGER*2 P,O,PDUM,OVARIE,TESTES
      REAL*4 IW,INTAKE,IB
      REAL*8 HEAD1
C
      COMMON/BLK1/HEAD1(2,10),HEAD2(2,12),HEAD3(2),HEAD4(2,5),
     1DIALNU,NN,NWLBOD,NCARB,IPRINT,OVARIE,TESTES,XLABEL(30)
C
      COMMON/BLK2/D(5,10),RI(3),CF(3),WATER(30),
     1POP(30),USEFR(30),GENVAR(30),PD(30),INTAKE(30),
     2F(30),CP(30),FRCARB(30),DOSSUM(10),HEFSUM(12),
     3HEGSUM(12),IP1(30),IP2(30),IP3(30),HECON(10),HE(10),
     4VG,VW,SOF(30),IW,IB
C
C  EXTERNAL DOSE--AIR SUBMERSION.  P=8,11,18,23
C
C
      DOSNF=GENVAR(P)*PD(P)*USEFR(P)*D(IP1(P),O)*SOF(P)
C
      RETURN
      END
C  ********************
C
```

```
      FUNCTION DOSNG(P,O)
C
C
      INTEGER*2 P,O,PDUM,OVARIE,TESTES
      REAL*4 IW,INTAKE,IB
      REAL*8 HEAD1
C
      COMMON/BLK1/HEAD1(2,10),HEAD2(2,12),HEAD3(2),HEAD4(2,5),
     1DIALNU,NN,NWLBOD,NCARB,IPRINT,OVARIE,TESTES,XLABEL(30)
C
      COMMON/BLK2/D(5,10),RI(3),CF(3),WATER(30),
     1POP(30),USEFR(30),GENVAR(30),PD(30),INTAKE(30),
     2F(30),CP(30),FRCARB(30),DOSSUM(10),HEFSUM(12),
     3HEGSUM(12),IP1(30),IP2(30),IP3(30),HECON(10),HE(10),
     4VG,VW,SOF(30),IW,IB
C
C  ABOVE SURFACE CROPS,MILK,BEEF INGESTION.  P=19,20,21
C
C
      DOSNG=VG*D(IP1(P),O)*RI(IP3(P))*F(P)*CP(P)*GENVAR(P)
C
      RETURN
      END
C  ********************
C
```

```
      FUNCTION DOSNH(P,O)
C
C
      INTEGER*2 P,O,PDUM,OVARIE,TESTES
      REAL*4 IW,INTAKE,IB
      REAL*8 HEAD1
C
      COMMON/BLK1/HEAD1(2,10),HEAD2(2,12),HEAD3(2),HEAD4(2,5),
     1DIALNU,NN,NWLBOD,NCARB,IPRINT,OVARIE,TESTES,XLABEL(30)
C
      COMMON/BLK2/D(5,10),RI(3),CF(3),WATER(30),
     1POP(30),USEFR(30),GENVAR(30),PD(30),INTAKE(30),
     2F(30),CP(30),FRCARB(30),DOSSUM(10),HEFSUM(12),
     3HEGSUM(12),IP1(30),IP2(30),IP3(30),HECON(10),HE(10),
     4VG,VW,SOF(30),IW,IB
C
C  OCEAN FISH AND SHELLFISH INGESTION.  P=29,30
C
C
      DOSNH=CF(IP2(P))*INTAKE(P)*POP(P)*D(IP1(P),O)*VW*
     1GENVAR(P)/WATER(P)
C
      RETURN
      END
C  ********************
C
```

```
      FUNCTION DOSNI(P,O)
C
C
      INTEGER*2 P,O,PDUM,OVARIE,TESTES
      REAL*4 IW,INTAKE,IB
      REAL*8 HEAD1
C
      COMMON/BLK1/HEAD1(2,10),HEAD2(2,12),HEAD3(2),HEAD4(2,5),
     1DIALNU,NN,NWLBOD,NCARB,IPRINT,OVARIE,TESTES,XLABEL(30)
C
      COMMON/BLK2/D(5,10),RI(3),CF(3),WATER(30),
     1POP(30),USEFR(30),GENVAR(30),PD(30),INTAKE(30),
     2F(30),CP(30),FRCARB(30),DOSSUM(10),HEFSUM(12),
     3HEGSUM(12),IP1(30),IP2(30),IP3(30),HECON(10),HE(10),
     4VG,VW,SOF(30),IW,IB
C
C  HANDLES ALL DOSE CALCULATIONS FOR C-14 FOR VOLCANO/METEORITE
C  PATHWAYS, P=17 THROUGH 30.
C
      IF(D(IP1(P),NWLBOD).EQ.0..AND.D(IP1(P),O).NE.0.)GO TO 20
      IF(D(IP1(P),NWLBOD).EQ.0..AND.D(IP1(P),O).EQ.0.)GO TO 40
      DOSNI=FRCARB(P)*D(IP1(P),O)/D(IP1(P),NWLBOD)
      GO TO 60
20    WRITE(6,965)
40    DOSNI=0.
965   FORMAT(/2X,'YOU IDIOT--YOU HAVE SET WHOLE BODY DOSE',
     1' FACTOR FOR CARBON TO ZERO WITHOUT SETTING'/2X,'OTHER ',
     2' DOSE FACTORS TO ZERO'/)
C
60    RETURN
      END
```

APPENDIX F

SAMPLE RUN OF WESP
ENVIRONMENTAL DOSE COMMITMENT ESTIMATES

```
                                        INPUT DATA

CALCULATION OPTION(IPRINT)= 2

IW= 6.030E+02 L/Y     IB= 8.401E+03 M**3/Y     NN= 19    MAXO= 10    MAXP= 30    MAXSUM= 12

NWLBOD=  8     NCARB=  1     OVARIE=  9     TESTES= 10

                                                       PATHWAY DEPENDENT INPUT DATA

 P WATER(P)   POP(P)     USEFR(P) GENVAR(P)   PD(P)     INTAKE(P)    F(P)      CP(P)   FRCARB(P)   SOF(P)    IP1  IP2  IP3    P
                                                                              PERSONS
   L/Y OR L    MAN                   1/M     MAN/M**2     KG/Y                FED/M**2
 1 3.000E+16 1.000E+10 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0          3    0    0    1
 2 3.000E+16 1.000E+10 0.0        0.0        0.0        1.000E+00  0.0        0.0        0.0        0.0          3    1    0    2
 3 0.0       0.0       5.000E-01  0.0        0.0        0.0        5.000E-01  1.000E-03  0.0        0.0          3    0    1    3
 4 0.0       0.0       5.000E-01  0.0        0.0        0.0        2.500E-01  1.500E-03  0.0        0.0          3    0    2    4
 5 0.0       0.0       5.000E-01  0.0        0.0        0.0        2.500E-01  2.100E-04  0.0        0.0          3    0    3    5
 6 0.0       0.0       5.000E-01  1.000E-09  6.670E-05  0.0        0.0        0.0        0.0        0.0          2    0    0    6
 7 0.0       0.0       5.000E-01  0.0        6.670E-05  0.0        0.0        0.0        0.0        3.330E-01    5    0    0    7
 8 0.0       0.0       5.000E-01  1.000E-09  6.670E-05  0.0        0.0        0.0        0.0        3.330E-01    4    0    0    8
 9 2.700E+19 1.000E+10 0.0        0.0        0.0        6.000E+00  0.0        0.0        0.0        0.0          3    2    0    9
10 2.700E+19 1.000E+10 0.0        0.0        0.0        1.000E+00  0.0        0.0        0.0        0.0          3    3    0   10
11 0.0       0.0       1.000E+00  1.000E-09  6.670E-05  0.0        0.0        0.0        0.0        1.000E+00    4    0    0   11
12 0.0       0.0       1.000E+00  1.000E-09  6.670E-05  0.0        0.0        0.0        0.0        0.0          1    0    0   12
13 0.0       0.0       1.000E+00  0.0        0.0        0.0        2.300E-01  1.000E-03  0.0        0.0          3    0    1   13
14 0.0       0.0       1.000E+00  0.0        0.0        0.0        1.100E-01  1.500E-03  0.0        0.0          3    0    2   14
15 0.0       0.0       1.000E+00  0.0        0.0        0.0        1.100E-01  2.100E-04  0.0        0.0          3    0    3   15
16 0.0       0.0       1.000E+00  0.0        6.670E-05  0.0        0.0        0.0        0.0        1.000E+00    5    0    0   16
17 0.0       0.0       1.000E+00  7.720E-05  6.670E-05  0.0        0.0        0.0        1.000E-02  0.0          1    0    0   17
18 0.0       0.0       1.000E+00  7.720E-05  6.670E-05  0.0        0.0        0.0        0.0        1.000E+00    4    0    0   18
19 0.0       0.0       0.0        7.720E-05  0.0        0.0        2.300E-01  1.000E-03  9.900E-01  0.0          3    0    1   19
20 0.0       0.0       0.0        7.720E-05  0.0        0.0        1.100E-01  1.500E-03  0.0        0.0          3    0    2   20
21 0.0       0.0       0.0        7.720E-05  0.0        0.0        1.100E-01  2.100E-04  0.0        0.0          3    0    3   21
22 0.0       0.0       1.000E+00  0.0        6.670E-05  0.0        0.0        0.0        0.0        1.000E+00    5    0    0   22
23 0.0       0.0       1.000E+00  1.000E-09  6.670E-05  0.0        0.0        0.0        0.0        1.000E+00    4    0    0   23
24 0.0       0.0       1.000E+00  1.000E-09  6.670E-05  0.0        0.0        0.0        1.000E-02  0.0          1    0    0   24
25 0.0       0.0       1.000E+00  0.0        0.0        0.0        2.300E-01  1.000E-03  9.900E-01  0.0          3    0    1   25
26 0.0       0.0       1.000E+00  0.0        0.0        0.0        1.100E-01  1.500E-03  0.0        0.0          3    0    2   26
27 0.0       0.0       1.000E+00  0.0        0.0        0.0        1.100E-01  2.100E-04  0.0        0.0          3    0    3   27
28 0.0       0.0       1.000E+00  0.0        6.670E-05  0.0        0.0        0.0        0.0        1.000E+00    5    0    0   28
29 2.700E+19 1.000E+10 0.0        7.720E-05  0.0        6.000E+00  0.0        0.0        1.000E+00  0.0          3    2    0   29
30 2.700E+19 1.000E+10 0.0        7.720E-05  0.0        1.000E+00  0.0        0.0        0.0        0.0          3    3    0   30
```

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```
                          HEALTH EFFECTS CONVERSION FACTORS,  HEALTH EFFECTS/MAN REM
(FATAL CANCERS FOR ALL ORGANS EXCEPT OVARIES AND TESTES.  GENETIC EFFECTS TO FIRST GENERATION FOR OVARIES AND TESTES)

   BONE      RED MARROW     LUNGS       LIVER       GI-LLI      THYROID     KIDNEYS    OTHERORGAN   OVARIES      TESTES
                                                     WALL

1.000E-05   4.000E-05   4.000E-05   1.000E-05   2.000E-05   1.000E-06   1.000E-05   7.000E-05   2.000E-05   2.000E-05


                                               NUCLIDE DEPENDENT INPUT DATA

NUCLIDE  PATHWAY                          DOSE COMMITMENT FACTORS
(INHALATION AND INGESTION=REM/CI INTAKE    AIR SUBMERSION=REM/Y PER CI/M**3   GROUND CONTAMINATION=REM/Y PER CI/M**2)

                                                      ORGAN

                    BONE    RED MARROW   LUNGS     LIVER     GI-LLI    THYROID   KIDNEYS  OTHERORGAN  OVARIES   TESTES
                                                              WALL

C-14      INHAL1  8.460E+00 2.420E+01 6.180E+00 8.880E+00 7.220E+00 6.480E+00 7.920E+00 1.410E+01 5.290E+00 5.420E+00
          INHAL2  8.460E+00 2.420E+01 6.180E+00 8.880E+00 7.220E+00 6.480E+00 7.920E+00 1.410E+01 5.290E+00 5.420E+00
          INGEST  1.170E+03 3.380E+03 8.490E+02 1.230E+03 1.460E+03 8.890E+02 1.060E+03 1.920E+03 7.360E+02 7.230E+02
         EXT AIR  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
         EXT GND  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

NI-59     INHAL1  1.290E+04 2.150E+03 8.470E+03 4.983E+03 7.120E+02 2.150E+03 2.150E+03 2.150E+03 2.150E+03 2.150E+03
          INHAL2  1.290E+04 2.150E+03 8.470E+03 4.980E+03 3.560E+02 2.150E+03 2.150E+03 2.150E+03 2.150E+03 2.150E+03
          INGEST  9.670E+03 1.610E+03 1.610E+03 3.320E+03 9.700E+02 1.610E+03 1.610E+03 1.610E+03 1.610E+03 1.610E+03
         EXT AIR  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
         EXT GND  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

SR-90     INHAL1  3.210E+05 1.210E+05 8.540E+06 1.930E+04 9.310E+05 3.740E+03 3.740E+03 1.510E+05 3.740E+03 3.730E+03
          INHAL2  3.000E+06 1.100E+06 4.920E+04 1.490E+04 5.500E+04 1.540E+04 1.540E+04 2.410E+05 1.540E+04 1.540E+04
          INGEST  1.200E+06 4.300E+05 1.570E-02 5.710E+03 1.980E+05 5.990E+03 5.990E+03 9.500E+04 5.990E+03 5.990E+03
         EXT AIR  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
         EXT GND  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

ZR-93     INHAL1  1.470E+03 1.750E+03 5.850E+04 2.930E+03 7.160E+03 1.600E+03 1.360E+03 2.500E+03 1.040E+03 1.470E+02
          INHAL2  4.120E+03 2.460E+03 3.080E+04 2.110E+03 6.980E+03 1.320E+03 1.320E+03 2.130E+03 1.460E+03 4.950E+02
          INGEST  1.970E+02 3.340E+02 3.900E+01 1.430E+02 1.750E+04 1.690E+01 1.990E+02 2.470E+02 1.360E+03 1.340E+02
         EXT AIR  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
         EXT GND  1.780E+04 1.780E+04 1.780E+04 1.780E+04 1.780E+04 1.780E+04 1.780E+04 1.780E+04 1.780E+04 1.780E+04

TC-99     INHAL1  2.420E+02 2.150E+02 5.220E+04 4.210E+02 1.660E+03 9.460E+03 3.070E+02 8.870E+02 2.120E+02 2.120E+02
          INHAL2  2.420E+02 2.150E+02 5.220E+04 4.210E+02 1.660E+03 9.460E+03 3.070E+02 8.870E+02 2.120E+02 2.120E+02
          INGEST  3.610E+02 3.220E+02 0.0       6.280E+02 3.200E+03 1.410E+04 4.580E+02 2.140E+02 3.170E+02 3.170E+02
         EXT AIR  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
         EXT GND  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
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ORGAN

		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
SN-126	INHAL1	1.580E+05	1.580E+05	1.270E+06	4.190E+03	7.600E+04	1.230E+03	6.160E+03	6.160E+03	6.160E+03	6.160E+03
	INHAL2	1.580E+05	1.580E+05	1.270E+06	4.190E+03	7.600E+04	1.230E+03	6.160E+03	6.160E+03	6.160E+03	6.160E+03
	INGEST	8.570E+04	8.570E+04	3.110E+03	1.690E+03	1.180E+05	4.990E+02	2.830E+03	2.820E+03	2.820E+03	2.820E+03
	EXT AIR	1.150E+07	1.150E+07	1.150E+07	1.150E+07	1.150E+07	1.150E+07	1.150E+07	1.150E+07	1.150E+07	1.150E+07
	EXT GND	2.090E+05	2.090E+05	2.090E+05	2.090E+05	2.090E+05	2.090E+05	2.090E+05	2.090E+05	2.090E+05	2.090E+05
I-129	INHAL1	5.790E+02	6.050E+02	7.880E+02	4.660E+02	4.280E+01	5.000E+06	4.490E+02	2.050E+03	3.780E+02	3.570E+02
	INHAL2	5.790E+02	6.050E+02	7.880E+02	4.660E+02	4.280E+01	5.000E+06	4.490E+02	2.050E+03	3.780E+02	3.570E+02
	INGEST	9.020E+02	9.420E+02	1.790E+02	7.240E+02	6.700E+01	7.800E+06	7.020E+02	3.180E+03	5.920E+02	5.580E+02
	EXT AIR	1.450E+05	1.310E+05	4.850E+04	3.600E+04	1.150E+04	1.010E+05	5.380E+04	9.540E+04	3.400E+04	1.310E+05
	EXT GND	8.730E+03	7.870E+03	2.910E+03	2.160E+03	6.900E+02	6.040E+03	3.230E+03	5.730E+03	2.040E+03	7.880E+03
CS-135	INHAL1	7.470E+03	7.470E+03	6.400E+02	7.470E+03	8.510E+01	7.480E+03	7.470E+03	4.400E+03	7.470E+03	7.470E+03
	INHAL2	7.470E+03	7.470E+03	6.400E+02	7.470E+03	8.510E+01	7.480E+03	7.470E+03	4.400E+03	7.470E+03	7.470E+03
	INGEST	1.120E+04	1.120E+04	0.0	1.120E+04	5.350E+02	1.130E+04	1.120E+04	6.610E+03	1.120E+04	1.120E+04
	EXT AIR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	EXT GND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CS-137	INHAL1	4.540E+04	4.910E+04	1.620E+04	5.230E+04	1.600E+04	4.470E+04	5.130E+04	3.260E+04	5.000E+04	4.440E+04
	INHAL2	4.540E+04	4.910E+04	1.620E+04	5.230E+04	1.600E+04	4.470E+04	5.130E+04	3.260E+04	5.000E+04	4.440E+04
	INGEST	6.820E+04	7.380E+04	1.990E+04	7.870E+04	2.590E+04	6.720E+04	7.730E+04	4.910E+04	7.540E+04	6.680E+04
	EXT AIR	4.660E+06	4.450E+06	3.600E+06	3.180E+06	2.750E+06	4.020E+06	3.380E+06	3.810E+06	1.390E+06	4.240E+06
	EXT GND	8.290E+04	7.920E+04	6.400E+04	5.650E+04	4.900E+04	7.150E+04	6.030E+04	6.790E+04	2.490E+04	7.550E+04
SM-151	INHAL1	5.100E+02	2.090E+02	6.780E+04	1.900E+03	3.040E+03	1.920E+01	5.540E+02	1.090E+03	1.470E+01	1.070E+01
	INHAL2	4.910E+03	1.940E+03	1.590E+04	1.890E+04	2.810E+03	1.040E+02	5.380E+03	1.190E+03	1.090E+02	1.030E+02
	INGEST	4.910E+00	3.200E+00	1.050E-01	1.730E+01	5.850E+03	1.030E-01	5.520E+00	2.340E+01	5.660E+00	5.360E-01
	EXT AIR	2.440E+01	2.130E+01	4.240E+00	2.350E+00	2.920E+00	9.060E+00	7.020E+00	3.070E+01	3.920E+00	3.880E+01
	EXT GND	4.590E+00	4.000E+00	7.960E-01	4.410E-01	5.480E-01	1.700E+00	1.320E+00	5.780E+00	7.360E-01	7.300E+00
RA-226	INHAL1	1.100E+07	9.800E+05	2.810E+07	3.400E+05	1.000E+05	3.400E+05	3.490E+05	4.600E+06	3.400E+05	3.400E+05
	INHAL2	1.100E+07	9.800E+05	2.810E+07	3.400E+05	1.000E+05	3.400E+05	3.490E+05	4.600E+06	3.400E+05	3.400E+05
	INGEST	6.320E+07	2.140E+06	2.710E+02	1.870E+06	8.160E+05	8.010E+05	5.790E+06	7.790E+06	8.060E+05	8.010E+05
	EXT AIR	1.500E+07	1.390E+07	1.270E+07	1.120E+07	1.030E+07	1.280E+07	1.060E+07	1.180E+07	9.900E+06	1.130E+07
	EXT GND	2.520E+05	2.340E+05	2.070E+05	1.850E+05	1.690E+05	2.120E+05	1.750E+05	2.210E+05	1.630E+05	1.890E+05
U-234	INHAL1	2.000E+07	8.100E+05	2.730E+08	5.900E+05	5.480E+04	5.900E+05	8.700E+05	9.800E+06	5.900E+05	5.900E+05
	INHAL2	5.900E+07	2.400E+06	2.800E+07	1.700E+06	4.790E+04	1.700E+06	2.500E+06	5.500E+06	1.700E+06	1.700E+06
	INGEST	2.000E+07	8.000E+05	8.230E+02	5.800E+05	8.860E+04	5.800E+05	8.500E+05	1.700E+06	5.800E+05	5.800E+05
	EXT AIR	2.940E+03	2.640E+03	1.030E+03	7.640E+02	8.560E+02	1.280E+03	8.130E+02	2.490E+03	6.640E+02	2.090E+03
	EXT GND	5.630E+02	5.050E+02	1.970E+02	1.460E+02	1.640E+02	2.460E+02	1.560E+02	4.780E+02	1.270E+02	4.000E+02
NP-237	INHAL1	9.040E+08	3.010E+08	2.900E+08	4.020E+08	1.380E+05	3.000E+06	5.200E+07	8.500E+07	1.800E+06	5.800E+06
	INHAL2	2.240E+09	7.470E+08	3.000E+07	9.910E+08	1.260E+05	7.400E+06	1.280E+08	1.900E+08	4.600E+06	1.400E+07
	INGEST	1.900E+07	6.200E+06	8.870E+02	8.200E+06	1.460E+05	6.080E+04	1.100E+06	1.600E+06	3.900E+04	1.200E+05
	EXT AIR	3.270E+06	3.030E+06	1.790E+06	1.560E+06	1.130E+06	2.150E+06	1.500E+06	2.050E+06	1.020E+06	2.410E+06
	EXT GND	7.250E+04	6.720E+04	3.970E+04	3.460E+04	2.500E+04	4.470E+04	3.340E+04	4.570E+04	2.270E+04	5.350E+04

		ORGAN									
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
PU-238	INHAL1	7.910E+08	2.640E+08	3.090E+08	3.550E+08	6.200E+04	2.600E+06	4.600E+07	7.600E+07	1.600E+06	5.000E+06
	INHAL2	2.030E+09	6.770E+08	3.200E+07	9.070E+08	5.510E+04	6.600E+06	1.170E+08	1.730E+08	4.100E+06	1.300E+07
	INGEST	5.000E+05	1.700E+05	7.890E-02	2.200E+05	1.100E+05	1.640E+03	2.910E+04	4.320E+04	1.030E+03	3.200E+03
	EXT AIR	1.260E+03	1.090E+03	3.020E+02	1.330E+02	4.450E+02	2.460E+02	1.770E+02	1.660E+03	1.860E+02	1.320E+03
	EXT GND	2.470E+02	2.140E+02	5.920E+01	2.600E+01	8.710E+01	4.810E+01	3.460E+01	3.250E+02	3.640E+01	2.580E+02
PU-239	INHAL1	9.120E+08	3.040E+08	2.940E+08	4.040E+08	5.780E+04	3.000E+06	5.200E+07	8.600E+07	1.800E+06	5.800E+06
	INHAL2	2.280E+09	7.610E+08	3.000E+07	1.000E+09	5.130E+04	7.400E+06	1.300E+08	1.920E+08	4.600E+06	1.500E+07
	INGEST	5.700E+05	1.900E+05	6.090E-02	2.500E+05	9.860E+04	1.850E+03	3.220E+04	4.820E+04	1.150E+03	3.600E+03
	EXT AIR	6.410E+02	5.610E+02	1.710E+02	9.380E+01	1.900E+02	1.890E+02	1.230E+02	7.220E+02	1.170E+02	6.110E+02
	EXT GND	1.220E+02	1.070E+02	3.240E+01	1.780E+01	3.600E+01	3.590E+01	2.330E+01	1.370E+02	2.210E+01	1.160E+02
PU-240	INHAL1	9.130E+08	3.040E+08	2.950E+08	4.050E+08	5.820E+04	3.000E+06	5.200E+07	8.600E+07	1.800E+06	5.800E+06
	INHAL2	2.280E+09	7.600E+08	3.100E+07	1.010E+09	5.170E+04	7.400E+06	1.300E+08	1.940E+08	4.600E+06	1.500E+07
	INGEST	5.700E+05	1.900E+05	8.320E-02	2.500E+05	9.930E+04	1.840E+03	3.220E+04	4.830E+04	1.150E+03	3.600E+03
	EXT AIR	1.160E+03	1.000E+03	2.890E+02	1.400E+02	3.990E+02	2.530E+02	1.780E+02	1.460E+03	1.800E+02	1.170E+03
	EXT GND	2.250E+02	1.960E+02	5.640E+01	2.720E+01	7.790E+01	4.930E+01	3.470E+01	2.850E+02	3.520E+01	2.280E+02
AM-241	INHAL1	9.430E+08	3.140E+08	3.130E+08	4.190E+08	6.520E+04	3.100E+06	5.400E+07	8.900E+07	1.900E+06	6.000E+06
	INHAL2	2.350E+09	7.830E+08	3.200E+07	1.040E+09	6.110E+04	7.700E+06	1.340E+08	1.990E+08	4.800E+06	1.500E+07
	INGEST	1.900E+07	6.400E+06	1.270E+02	8.500E+06	1.100E+05	6.320E+04	1.100E+06	1.600E+06	3.940E+04	1.200E+05
	EXT AIR	2.720E+05	2.480E+05	1.010E+05	8.300E+04	5.680E+04	1.380E+05	8.800E+04	1.440E+05	8.510E+04	1.260E+05
	EXT GND	1 420E+04	1.300E+04	5.300E+03	4.330E+03	2.960E+03	7.210E+03	4.590E+03	7.500E+03	4.440E+03	6.570E+03
PU-242	INHAL1	8.690E+08	2.890E+08	2.800E+08	3.850E+08	5.510E+04	2.800E+06	5.000E+07	8.200E+07	1.800E+06	5.500E+06
	INHAL2	2.170E+09	7.220E+08	2.900E+07	9.560E+08	4.900E+04	7.100E+06	1.230E+08	1.840E+08	4.400E+06	1.400E+07
	INGEST	5.400E+05	1.800E+05	1.600E-01	2.400E+05	9.400E+04	1.760E+03	3.060E+04	4.600E+04	1.090E+03	3.420E+03
	EXT AIR	1.040E+03	8.930E+02	2.360E+02	9.370E+01	3.650E+02	1.770E+02	1.320E+02	1.390E+03	1.510E+02	1.100E+03
	EXT GND	2.030E+02	1.750E+02	4.630E+01	1.840E+01	7.160E+01	3.470E+01	2.590E+01	2.720E+02	2.970E+01	2.170E+02
AM-243	INHAL1	9.430E+08	1.560E+09	3.030E+08	4.210E+08	3.220E+05	3.100E+06	5.400E+07	8.900E+07	1.900E+06	6.000E+06
	INHAL2	2.340E+09	3.870E+09	3.100E+07	1.040E+09	1.500E+05	7.700E+06	1.340E+08	1.990E+08	4.800E+06	1.500E+07
	INGEST	1.900E+07	3.200E+07	9.640E+02	8.500E+06	1.490E+05	6.340E+04	1.100E+06	1.600E+06	4.070E+04	1.200E+05
	EXT AIR	2.170E+06	2.010E+06	1.060E+06	9.140E+05	6.490E+05	1.330E+06	8.970E+05	1.290E+06	6.760E+05	1.410E+06
	EXT GND	5.290E+04	4.880E+04	2.630E+04	2.260E+04	1.610E+04	3.260E+04	2.210E+04	3.150E+04	1.650E+04	3.480E+04

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                            **********CF(N,IP2)**********  *********RI(N,IP3)**********
                                  CI/KG PER CI/L         CI INTAKE PER CI/M**2 DEPOSITED   VG(N)     VW(N)
                              IP2= 1    IP2= 2    IP2= 3    IP3= 1    IP3= 2    IP3= 3     M/Y       M/Y
NUCLIDE  DIALNU(N)  N


 C-14       6.014   1   4.550E+03 1.000E+00 1.000E+00 3.250E+02 1.610E+02 4.240E+02 3.160E+05 6.310E+05
 NI-59     28.059   2   1.000E+02 5.000E+02 1.000E+02 3.950E+00 1.280E+00 7.720E+00 3.160E+05 6.310E+05
 SR-90     38.090   3   5.000E+00 1.000E+00 1.000E+00 1.056E+01 1.040E+00 9.890E-02 3.160E+05 6.310E+05
 ZR-93     40.093   4   3.330E+00 3.000E+01 1.000E+02 3.110E+00 1.292E+01 4.170E+00 3.160E+05 6.310E+05
 TC-99     43.099   5   1.500E+01 1.000E+01 1.000E+02 6.370E+00 2.770E+00 1.840E+00 3.160E+05 6.310E+05
 SN-126    50.126   6   3.000E+03 3.000E+00 3.000E+00 3.800E+00 2.240E-01 1.134E+01 3.160E+05 6.310E+05
 I-129     53.129   7   1.500E+01 2.000E+01 1.000E+02 3.180E+00 1.610E+00 8.670E-01 3.160E+05 6.310E+05
 CS-135    55.135   8   4.000E+02 3.000E+01 5.000E+01 6.700E+00 4.200E+00 7.950E+00 3.160E+05 6.310E+05
 CS-137    55.137   9   4.000E+02 3.000E+01 5.000E+01 3.130E+00 1.110E+00 2.110E+00 3.160E+05 6.310E+05
 SM-151    62.151  10   2.500E+01 2.500E+01 1.000E+03 3.020E+00 7.910E-04 6.000E-01 3.160E+05 6.310E+05
 RA-226    88.226  11   5.000E+01 5.000E+01 1.000E+02 8.190E+00 1.330E-01 8.500E-02 3.160E+05 6.310E+05
 U-234     92.234  12   1.000E+01 1.000E+01 1.000E+01 1.360E+01 8.900E-02 7.730E-04 3.160E+05 6.310E+05
 NP-237    93.237  13   1.000E+01 1.000E+01 1.000E+01 2.850E+00 7.600E-04 2.300E-02 3.160E+05 6.310E+05
 PU-238    94.238  14   3.500E+02 3.500E+00 1.000E+02 2.910E+00 8.290E-06 2.260E-06 3.160E+05 6.310E+05
 PU-239    94.239  15   3.500E+02 3.500E+00 1.000E+02 4.680E+00 1.340E-05 3.650E-06 3.160E+05 6.310E+05
 PU-240    94.240  16   3.500E+02 3.500E+00 1.000E+02 4.420E+00 1.280E-05 3.490E-06 3.160E+05 6.310E+05
 AM-241    95.241  17   2.500E+01 2.500E+01 1.000E+03 3.420E+00 6.760E-03 2.270E-04 3.160E+05 6.310E+05
 PU-242    94.242  18   3.500E+02 3.500E+00 1.000E+02 4.770E+00 1.160E-05 8.000E-05 3.160E+05 6.310E+05
 AM-243    95.243  19   2.500E+01 2.500E+01 1.000E+03 5.060E+00 1.040E-02 3.520E-04 3.160E+05 6.310E+05
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INTERIM FACTORS FOR POPULATION DOSE AS A FUNCTION OF NUCLIDE AND ORGAN

NUCLIDE	PATHWAYS SUMMED	ORGAN									
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
C-14	1-5	1.454E+02	4.201E+02	1.055E+02	1.529E+02	1.815E+02	1.105E+02	1.317E+02	2.386E+02	4.574E+01	4.493E+01
C-14	6-8	2.370E-09	6.780E-09	1.731E-09	2.488E-09	2.023E-09	1.816E-09	2.219E-09	3.950E-09	7.411E-10	7.593E-10
C-14	9-10	3.033E-06	8.763E-06	2.201E-06	3.189E-06	3.785E-06	2.305E-06	2.748E-06	4.978E-06	9.541E-07	9.372E-07
C-14	11-12	4.741E-09	1.356E-08	3.463E-09	4.976E-09	4.046E-09	3.631E-09	4.438E-09	7.901E-09	1.482E-09	1.519E-09
C-14	13-15	1.300E+02	3.755E+02	9.433E+01	1.367E+02	1.622E+02	9.878E+01	1.178E+02	2.133E+02	4.089E+01	4.017E+01
C-14	16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C-14	17-21	6.093E-01	1.760E+00	4.421E-01	6.405E-01	7.579E-01	4.630E-01	5.522E-01	1.000E+00	1.916E-01	1.883E-01
C-14	22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C-14	23-24	6.000E-03	1.716E-02	4.383E-03	6.298E-03	5.121E-03	4.596E-03	5.617E-03	1.000E-02	1.876E-03	1.922E-03
C-14	25-27	6.033E-01	1.743E+00	4.378E-01	6.342E-01	7.528E-01	4.584E-01	5.466E-01	9.900E-01	1.897E-01	1.864E-01
C-14	28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C-14	29 -30	6.094E-01	1.760E+00	4.422E-01	6.406E-01	7.604E-01	4.630E-01	5.521E-01	1.000E+00	1.917E-01	1.883E-01
NI-59	1-5	1.610E+01	2.680E+00	2.680E+00	5.526E+00	1.615E+00	2.680E+00	2.680E+00	2.680E+00	1.340E+00	1.340E+00
NI-59	6-8	3.614E-06	6.024E-07	2.373E-06	1.395E-06	9.974E-08	6.024E-07	6.024E-07	6.024E-07	3.012E-07	3.012E-07
NI-59	9-10	1.110E-02	1.849E-03	1.849E-03	3.812E-03	1.114E-03	1.849E-03	1.849E-03	1.849E-03	9.243E-04	9.243E-04
NI-59	11-12	7.228E-06	1.205E-06	4.746E-06	2.792E-06	3.990E-07	1.205E-06	1.205E-06	1.205E-06	6.024E-07	6.024E-07
NI-59	13-15	1.255E+01	2.090E+00	2.090E+00	4.309E+00	1.259E+00	2.090E+00	2.090E+00	2.090E+00	1.045E+00	1.045E+00
NI-59	16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NI-59	17-21	3.068E+02	5.107E+01	5.135E+01	1.053E+02	3.075E+01	5.107E+01	5.107E+01	5.107E+01	2.554E+01	2.554E+01
NI-59	22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NI-59	23-24	7.228E-06	1.205E-06	4.746E-06	2.792E-06	3.990E-07	1.205E-06	1.205E-06	1.205E-06	6.024E-07	6.024E-07
NI-59	25-27	1.255E+01	2.090E+00	2.090E+00	4.309E+00	1.259E+00	2.090E+00	2.090E+00	2.090E+00	1.045E+00	1.045E+00
NI-59	28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NI-59	29 -30	5.408E-01	9.005E-02	9.005E-02	1.857E-01	5.425E-02	9.005E-02	9.005E-02	9.005E-02	4.502E-02	4.502E-02
SR-90	1-5	3.648E+03	1.307E+03	4.773E-05	1.736E+01	6.020E+02	1.821E+01	1.821E+01	2.888E+02	9.106E+00	9.106E+00
SR-90	6-8	8.405E-04	3.082E-04	1.378E-05	4.175E-06	1.541E-05	4.315E-06	4.315E-06	6.752E-05	2.157E-06	2.157E-06
SR-90	9-10	3.111E-03	1.115E-03	4.070E-11	1.480E-05	5.133E-04	1.553E-05	1.553E-05	2.463E-04	7.765E-06	7.765E-06
SR-90	11-12	1.799E-04	6.780E-05	4.785E-03	1.081E-05	5.217E-04	2.096E-06	2.096E-06	8.461E-05	1.048E-06	1.045E-06
SR-90	13-15	3.123E+03	1.119E+03	4.086E-05	1.486E+01	5.153E+02	1.559E+01	1.559E+01	2.473E+02	7.795E+00	7.795E+00
SR-90	16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SR-90	17-21	7.621E+04	2.731E+04	3.694E+02	3.634E+02	1.261E+04	3.805E+02	3.805E+02	6.038E+03	1.902E+02	1.902E+02
SR-90	22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SR-90	23-24	1.799E-04	6.780E-05	4.785E-03	1.081E-05	5.217E-04	2.096E-06	2.096E-06	8.461E-05	1.048E-06	1.045E-06
SR-90	25-27	3.123E+03	1.119E+03	4.086E-05	1.486E+01	5.153E+02	1.559E+01	1.559E+01	2.473E+02	7.795E+00	7.795E+00
SR-90	28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SR-90	29 -30	1.516E-01	5.431E-02	1.983E-09	7.211E-04	2.501E-02	7.565E-04	7.565E-04	1.200E-02	3.782E-04	3.782E-04

NUCLIDE	PATHWAYS SUMMED	ORGAN BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
ZR-93	1-5	6.918E-01	1.173E+00	1.370E-01	5.022E-01	6.145E+01	5.935E-02	6.988E-01	8.674E-01	2.388E+00	2.353E-01
ZR-93	6-8	1.977E-01	1.977E-01	1.977E-01	1.977E-01	1.977E-01	1.977E-01	1.977E-01	1.977E-01	9.884E-02	9.884E-02
ZR-93	9-10	2.043E-05	3.464E-05	4.044E-06	1.483E-05	1.815E-03	1.753E-06	2.064E-05	2.561E-05	7.052E-05	6.948E-06
ZR-93	11-12	8.237E-07	9.806E-07	3.278E-05	1.642E-06	4.012E-06	8.966E-07	7.621E-07	1.401E-06	2.914E-07	4.119E-08
ZR-93	13-15	5.799E-01	9.831E-01	1.148E-01	4.209E-01	5.151E+01	4.974E-02	5.857E-01	7.270E-01	2.002E+00	1.972E-01
ZR-93	16	1.187E+00	1.187E+00	1.187E+00	1.187E+00	1.187E+00	1.187E+00	1.187E+00	1.187E+00	5.936E-01	5.936E-01
ZR-93	17-21	1.421E+01	2.406E+01	5.331E+00	1.039E+01	1.257E+03	1.283E+00	1.435E+01	1.784E+01	4.885E+01	4.814E+00
ZR-93	22	1.187E+00	1.187E+00	1.187E+00	1.187E+00	1.187E+00	1.187E+00	1.187E+00	1.187E+00	5.936E-01	5.936E-01
ZR-93	23-24	8.237E-07	9.806E-07	3.278E-05	1.642E-06	4.012E-06	8.966E-07	7.621E-07	1.401E-06	2.914E-07	4.119E-08
ZR-93	25-27	5.799E-01	9.831E-01	1.148E-01	4.209E-01	5.151E+01	4.974E-02	5.857E-01	7.270E-01	2.002E+00	1.972E-01
ZR-93	28	1.187E+00	1.187E+00	1.187E+00	1.187E+00	1.187E+00	1.187E+00	1.187E+00	1.187E+00	5.936E-01	5.936E-01
ZR-93	29 -30	9.952E-04	1.687E-03	1.970E-04	7.224E-04	8.841E-02	8.537E-05	1.005E-03	1.248E-03	3.435E-03	3.385E-04
TC-99	1-5	8.542E-01	7.619E-01	0.0	1.486E+00	7.572E+00	3.336E+01	1.084E+00	5.064E-01	3.750E-01	3.750E-01
TC-99	6-8	6.780E-08	6.024E-08	1.463E-05	1.180E-07	4.651E-07	2.650E-06	8.601E-08	2.485E-07	2.970E-08	2.970E-08
TC-99	9-10	2.139E-05	1.908E-05	0.0	3.721E-05	1.896E-04	8.356E-04	2.714E-05	1.268E-05	9.393E-06	9.393E-06
TC-99	11-12	1.356E-07	1.205E-07	2.925E-05	2.359E-07	9.302E-07	5.301E-06	1.720E-07	4.970E-07	5.940E-08	5.940E-08
TC-99	13-15	7.092E-01	6.326E-01	0.0	1.234E+00	6.287E+00	2.770E+01	8.998E-01	4.204E-01	3.114E-01	3.114E-01
TC-99	16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TC-99	17-21	1.731E+01	1.544E+01	2.258E+00	3.012E+01	1.534E+02	6.762E+02	2.196E+01	1.029E+01	7.601E+00	7.601E+00
TC-99	22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TC-99	23-24	1.356E-07	1.205E-07	2.925E-05	2.359E-07	9.302E-07	5.301E-06	1.720E-07	4.970E-07	5.940E-08	5.940E-08
TC-99	25-27	7.092E-01	6.326E-01	0.0	1.234E+00	6.287E+00	2.770E+01	8.998E-01	4.204E-01	3.114E-01	3.114E-01
TC-99	28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TC-99	29 -30	1.042E-03	9.295E-04	0.0	1.813E-03	9.237E-03	4.070E-02	1.322E-03	6.178E-04	4.575E-04	4.575E-04
SN-126	1-5	2.135E+02	2.135E+02	7.746E+00	4.209E+00	2.939E+02	1.243E+00	7.049E+00	7.024E+00	3.512E+00	3.512E+00
SN-126	6-8	2.321E+00	2.321E+00	2.321E+00	2.321E+00	2.321E+00	2.321E+00	2.321E+00	2.321E+00	1.161E+00	1.161E+00
SN-126	9-10	6.666E-04	6.666E-04	2.419E-05	1.314E-05	9.178E-04	3.881E-06	2.201E-05	2.193E-05	1.097E-05	1.097E-05
SN-126	11-12	8.930E-05	8.930E-05	7.124E-04	3.115E-06	4.335E-05	1.456E-06	4.219E-06	4.219E-06	2.109E-06	2.109E-06
SN-126	13-15	1.005E+02	1.005E+02	3.648E+00	1.982E+00	1.384E+02	5.853E-01	3.319E+00	3.308E+00	1.654E+00	1.654E+00
SN-126	16	1.394E+01	1.394E+01	1.394E+01	1.394E+01	1.394E+01	1.394E+01	1.394E+01	1.394E+01	6.970E+00	6.970E+00
SN-126	17-21	2.459E+03	2.459E+03	1.440E+02	4.860E+01	3.380E+03	1.439E+01	8.130E+01	8.102E+01	4.051E+01	4.051E+01
SN-126	22	1.394E+01	1.394E+01	1.394E+01	1.394E+01	1.394E+01	1.394E+01	1.394E+01	1.394E+01	6.970E+00	6.970E+00
SN-126	23-24	8.930E-05	8.930E-05	7.124E-04	3.115E-06	4.335E-05	1.456E-06	4.219E-06	4.219E-06	2.109E-06	2.109E-06
SN-126	25-27	1.005E+02	1.005E+02	3.648E+00	1.982E+00	1.384E+02	5.853E-01	3.319E+00	3.308E+00	1.654E+00	1.654E+00
SN-126	28	1.394E+01	1.394E+01	1.394E+01	1.394E+01	1.394E+01	1.394E+01	1.394E+01	1.394E+01	6.970E+00	6.970E+00
SN-126	29 -30	3.247E-02	3.247E-02	1.178E-03	6.403E-04	4.471E-02	1.891E-04	1.072E-03	1.068E-03	5.342E-04	5.342E-04

NUCLIDE	PATHWAYS SUMMED	ORGAN									
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
I-129	1-5	1.196E+00	1.249E+00	2.373E-01	9.598E-01	8.882E-02	1.034E+04	9.306E-01	4.216E+00	3.924E-01	3.699E-01
I-129	6-8	9.695E-02	8.740E-02	3.232E-02	2.399E-02	7.663E-03	6.848E-02	3.587E-02	6.364E-02	1.133E-02	4.376E-02
I-129	9-10	7.350E-05	7.676E-05	1.459E-05	5.899E-05	5.459E-06	6.356E-01	5.720E-05	2.591E-04	2.412E-05	2.273E-05
I-129	11-12	3.341E-07	3.477E-07	4.448E-07	2.635E-07	2.475E-08	2.802E-03	2.552E-07	1.155E-06	1.070E-07	1.044E-07
I-129	13-15	9.174E-01	9.581E-01	1.821E-01	7.364E-01	6.814E-02	7.933E+03	7.140E-01	3.234E+00	3.011E-01	2.838E-01
I-129	16	5.823E-01	5.249E-01	1.941E-01	1.441E-01	4.602E-02	4.029E-01	2.154E-01	3.822E-01	6.803E-02	2.628E-01
I-129	17-21	2.241E+01	2.340E+01	4.476E+00	1.798E+01	1.664E+00	1.937E+05	1.744E+01	7.899E+01	7.353E+00	6.931E+00
I-129	22	5.823E-01	5.249E-01	1.941E-01	1.441E-01	4.602E-02	4.029E-01	2.154E-01	3.822E-01	6.803E-02	2.628E-01
I-129	23-24	3.341E-07	3.477E-07	4.448E-07	2.635E-07	2.475E-08	2.802E-03	2.552E-07	1.155E-06	1.070E-07	1.044E-07
I-129	25-27	9.174E-01	9.581E-01	1.821E-01	7.364E-01	6.814E-02	7.933E+03	7.140E-01	3.234E+00	3.011E-01	2.838E-01
I-129	28	5.823E-01	5.249E-01	1.941E-01	1.441E-01	4.602E-02	4.029E-01	2.154E-01	3.822E-01	6.803E-02	2.628E-01
I-129	29 -30	3.580E-03	3.739E-03	7.105E-04	2.874E-03	2.659E-04	3.096E+01	2.786E-03	1.262E-02	1.175E-03	1.107E-03
CS-135	1-5	3.366E+01	3.366E+01	0.0	3.366E+01	1.608E+00	3.396E+01	3.366E+01	1.987E+01	1.683E+01	1.683E+01
CS-135	6-8	2.093E-06	2.093E-06	1.793E-07	2.093E-06	2.384E-08	2.096E-06	2.093E-06	1.233E-06	1.046E-06	1.046E-06
CS-135	9-10	9.541E-04	9.541E-04	0.0	9.541E-04	4.557E-05	9.626E-04	9.541E-04	5.631E-04	4.770E-04	4.770E-04
CS-135	11-12	4.186E-06	4.186E-06	3.586E-07	4.186E-06	4.769E-08	4.191E-06	4.186E-06	2.466E-06	2.093E-06	2.093E-06
CS-135	13-15	2.708E+01	2.708E+01	0.0	2.708E+01	1.293E+00	2.732E+01	2.708E+01	1.598E+01	1.354E+01	1.354E+01
CS-135	16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CS-135	17-21	6.609E+02	6.609E+02	2.769E-02	6.609E+02	3.156E+01	6.668E+02	6.609E+02	3.900E+02	3.304E+02	3.304E+02
CS-135	22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CS-135	23-24	4.186E-06	4.186E-06	3.586E-07	4.186E-06	4.769E-08	4.191E-06	4.186E-06	2.466E-06	2.093E-06	2.093E-06
CS-135	25-27	2.708E+01	2.708E+01	0.0	2.708E+01	1.293E+00	2.732E+01	2.708E+01	1.598E+01	1.354E+01	1.354E+01
CS-135	28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CS-135	29 -30	4.648E-02	4.648E-02	0.0	4.648E-02	2.220E-03	4.689E-02	4.648E-02	2.743E-02	2.324E-02	2.324E-02
CS-137	1-5	9.414E+01	1.019E+02	2.747E+01	1.086E+02	3.575E+01	9.276E+01	1.067E+02	6.777E+01	5.204E+01	4.610E+01
CS-137	6-8	9.207E-01	8.796E-01	7.108E-01	6.275E-01	5.442E-01	7.941E-01	6.697E-01	7.541E-01	1.383E-01	4.192E-01
CS-137	9-10	5.810E-03	6.287E-03	1.695E-03	6.704E-03	2.206E-03	5.724E-03	6.585E-03	4.183E-03	3.211E-03	2.845E-03
CS-137	11-12	2.575E-05	2.781E-05	9.318E-06	2.952E-05	9.149E-06	2.532E-05	2.897E-05	1.852E-05	1.406E-05	1.258E-05
CS-137	13-15	6.491E+01	7.024E+01	1.894E+01	7.491E+01	2.465E+01	6.396E+01	7.357E+01	4.673E+01	3.588E+01	3.179E+01
CS-137	16	5.529E+00	5.283E+00	4.269E+00	3.769E+00	3.268E+00	4.769E+00	4.022E+00	4.529E+00	8.304E-01	2.518E+00
CS-137	17-21	1.586E+03	1.716E+03	4.628E+02	1.830E+03	6.021E+02	1.562E+03	1.797E+03	1.141E+03	8.764E+02	7.765E+02
CS-137	22	5.529E+00	5.283E+00	4.269E+00	3.769E+00	3.268E+00	4.769E+00	4.022E+00	4.529E+00	8.304E-01	2.518E+00
CS-137	23-24	2.575E-05	2.781E-05	9.318F-06	2.952E-05	9.149E-06	2.532E-05	2.897E-05	1.852E-05	1.406E-05	1.258E-05
CS-137	25-27	6.491E+01	7.024E+01	1.894E+01	7.491E+01	2.465E+01	6.396E+01	7.357E+01	4.673E+01	3.588E+01	3.179E+01
CS-137	28	5.529E+00	5.283E+00	4.269E+00	3.769E+00	3.268E+00	4.769E+00	4.022E+00	4.529E+00	8.304E-01	2.518E+00
CS-137	29 -30	2.830E-01	3.062E-01	8.258E-02	3.266E-01	1.075E-01	2.789E-01	3.208E-01	2.037E-01	1.564E-01	1.386E-01

NUCLIDE	PATHWAYS SUMMED	ORGAN									
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
SM-151	1-5	4.813E-03	3.137E-03	1.029E-04	1.696E-02	5.734E+00	1.010E-04	5.411E-03	2.294E-02	2.774E-03	2.627E-04
SM-151	6-8	5.235E-05	4.497E-05	1.329E-05	1.019E-05	6.873E-06	1.891E-05	1.617E-05	6.452E-05	4.102E-06	4.055E-05
SM-151	9-10	2.091E-06	1.363E-06	4.472E-08	7.369E-06	2.492E-03	4.387E-08	2.351E-06	9.967E-06	1.205E-06	1.141E-07
SM-151	11-12	2.858E-07	1.171E-07	3.799E-05	1.065E-06	1.703E-06	1.076E-08	3.104E-07	6.108E-07	4.119E-09	2.999E-09
SM-151	13-15	3.479E-03	2.267E-03	7.440E-05	1.226E-02	4.145E+00	7.298E-05	3.911E-03	1.658E-02	2.005E-03	1.899E-04
SM-151	16	3.062E-04	2.668E-04	5.309E-05	2.941E-05	3.655E-05	1.134E-04	8.804E-05	3.855E-04	2.455E-05	2.435E-04
SM-151	17-21	1.069E-01	6.436E-02	2.935E+00	3.812E-01	1.013E+02	2.611E-03	1.194E-01	4.516E-01	4.924E-02	4.864E-03
SM-151	22	3.062E-04	2.668E-04	5.309E-05	2.941E-05	3.655E-05	1.134E-04	8.804E-05	3.855E-04	2.455E-05	2.435E-04
SM-151.	23-24	2.858E-07	1.171E-07	3.799E-05	1.065E-06	1.703E-06	1.076E-08	3.104E-07	6.108E-07	4.119E-09	2.999E-09
SM-151	25-27	3.479E-03	2.267E-03	7.440E-05	1.226E-02	4.145E+00	7.298E-05	3.911E-03	1.658E-02	2.005E-03	1.899E-04
SM-151	28	3.062E-04	2.668E-04	5.309E-05	2.941E-05	3.655E-05	1.134E-04	8.804E-05	3.855E-04	2.455E-05	2.435E-04
SM-151	29 -30	1.019E-04	6.639E-05	2.179E-06	3.589E-04	1.214E-01	2.137E-06	1.145E-04	4.855E-04	5.872E-05	5.561E-06
RA-226	1-5	1.449E+05	4.906E+03	6.212E-01	4.287E+03	1.871E+03	1.836E+03	1.327E+04	1.786E+04	9.238E+02	9.181E+02
RA-226	6-8	2.802E+00	2.599E+00	2.307E+00	2.055E+00	1.877E+00	2.354E+00	1.944E+00	2.456E+00	9.051E-01	1.050E+00
RA-226	9-10	9.363E+00	3.170E-01	4.015E-05	2.770E-01	1.209E-01	1.187E-01	8.578E-01	1.154E+00	5.970E-02	5.933E-02
RA-226	11-12	6.165E-03	5.501E-04	1.575E-02	1.913E-04	5.672E-05	1.914E-04	1.963E-04	2.578E-03	9.559E-05	9.564E-05
RA-226	13-15	1.206E+05	4.082E+03	5.170E-01	3.567E+03	1.557E+03	1.528E+03	1.105E+04	1.486E+04	7.688E+02	7.640E+02
RA-226	16	1.681E+01	1.561E+01	1.381E+01	1.234E+01	1.127E+01	1.414E+01	1.167E+01	1.474E+01	5.436E+00	6.303E+00
RA-226	17-21	2.942E+06	9.963E+04	1.228E+03	8.704E+04	3.798E+04	3.729E+04	2.695E+05	3.627E+05	1.376E+04	1.865E+04
RA-226	22	1.681E+01	1.561E+01	1.381E+01	1.234E+01	1.127E+01	1.414E+01	1.167E+01	1.474E+01	5.436E+00	6.303E+00
RA-226	23-24	6.165E-03	5.501E-04	1.575E-02	1.913E-04	5.672E-05	1.914E-04	1.963E-04	2.578E-03	9.559E-05	9.564E-05
RA-226	25-27	1.206E+05	4.082E+03	5.170E-01	3.567E+03	1.557E+03	1.528E+03	1.105E+04	1.486E+04	7.688E+02	7.640E+02
RA-226	28	1.681E+01	1.561E+01	1.381E+01	1.234E+01	1.127E+01	1.414E+01	1.167E+01	1.474E+01	5.436E+00	6.303E+00
RA-226	29 -30	4.561E+02	1.544E+01	1.956E-03	1.350E+01	5.889E+00	5.781E+00	4.179E+01	5.622E+01	2.908E+00	2.890E+00
U-234	1-5	7.242E+04	2.897E+03	2.980E+00	2.100E+03	3.208E+02	2.100E+03	3.078E+03	6.156E+03	1.050E+03	1.050E+03
U-234	6-8	2.278E-02	6.281E-03	1.003E-02	2.098E-03	1.835E-03	3.208E-03	2.433E-03	6.849E-03	9.433E-04	2.459E-03
U-234	9-10	5.185E-01	2.074E-02	2.134E-05	1.504E-02	2.297E-03	1.504E-02	2.204E-02	4.407E-02	7.519E-03	7.519E-03
U-234	11-12	1.121E-02	4.539E-04	1.530E-01	3.306E-04	3.071E-05	3.306E-04	4.875E-04	5.491E-03	1.653E-04	1.653E-04
U-234	13-15	6.285E+04	2.514E+03	2.586E+00	1.823E+03	2.784E+02	1.823E+03	2.671E+03	5.343E+03	9.114E+02	9.114E+02
U-234	16	3.755E-02	3.368E-02	1.314E-02	9.738E-03	1.094E-02	1.641E-02	1.041E-02	3.188E-02	4.235E-03	1.334E-02
U-234	17-21	1.534E+06	6.137E+04	1.187E+04	4.449E+04	6.795E+03	4.449E+04	6.520E+04	1.308E+05	2.225E+04	2.225E+04
U-234	22	3.755E-02	3.368E-02	1.314E-02	9.738E-03	1.094E-02	1.641E-02	1.041E-02	3.188E-02	4.235E-03	1.334E-02
U-234	23-24	1.121E-02	4.539E-04	1.530E-01	3.306E-04	3.071E-05	3.306E-04	4.875E-04	5.491E-03	1.653E-04	1.653E-04
U-234	25-27	6.285E+04	2.514E+03	2.586E+00	1.823E+03	2.784E+02	1.823E+03	2.671E+03	5.343E+03	9.114E+02	9.114E+02
U-234	28	3.755E-02	3.368E-02	1.314E-02	9.738E-03	1.094E-02	1.641E-02	1.041E-02	3.188E-02	4.235E-03	1.334E-02
U-234	29 -30	2.526E+01	1.010E+00	1.039E-03	7.325E-01	1.119E-01	7.325E-01	1.073E+00	2.147E+00	3.663E-01	3.663E-01

NUCLIDE	PATHWAYS SUMMED	ORGAN BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
NP-237	1-5	1.743E+04	5.689E+03	8.139E-01	7.524E+03	1.340E+02	5.579E+01	1.009E+03	1.468E+03	1.789E+01	5.505E+01
NP-237	6-8	1.433E+00	9.556E-01	4.493E-01	6.619E-01	2.777E-01	4.985E-01	4.068E-01	5.608E-01	1.267E-01	2.990E-01
NP-237	9-10	4.926E-01	1.607E-01	2.300E-05	2.126E-01	3.785E-03	1.576E-03	2.852E-02	4.148E-02	5.056E-04	1.556E-03
NP-237	11-12	5.066E-01	1.687E-01	1.625E-01	2.253E-01	7.740E-05	1.681E-03	2.914E-02	4.763E-02	5.043E-04	1.625E-03
NP-237	13-15	1.247E+04	4.068E+03	5.820E-01	5.380E+03	9.580E+01	3.989E+01	7.218E+02	1.050E+03	1.280E+01	3.937E+01
NP-237	16	4.836E+00	4.482E+00	2.648E+00	2.308E+00	1.667E+00	2.981E+00	2.228E+00	3.048E+00	7.570E-01	1.784E+00
NP-237	17-21	3.432E+05	1.123E+05	1.256E+04	1.486E+05	2.343E+03	1.103E+03	1.986E+04	2.929E+04	3.511E+02	1.086E+03
NP-237	22	4.836E+00	4.482E+00	2.648E+00	2.308E+00	1.667E+00	2.981E+00	2.228E+00	3.048E+00	7.570E-01	1.784E+00
NP-237	23-24	5.066E-01	1.687E-01	1.625E-01	2.253E-01	7.740E-05	1.681E-03	2.914E-02	4.763E-02	5.043E-04	1.625E-03
NP-237	25-27	1.247E+04	4.068E+03	5.820E-01	5.380E+03	9.580E+01	3.989E+01	7.218E+02	1.050E+03	1.280E+01	3.937E+01
NP-237	28	4.836E+00	4.482E+00	2.648E+00	2.308E+00	1.667E+00	2.981E+00	2.228E+00	3.048E+00	7.570E-01	1.784E+00
NP-237	29 -30	2.400E+01	7.830E+00	1.120E-03	1.036E+01	1.844E-01	7.679E-02	1.389E+00	2.021E+00	2.463E-02	7.578E-02
PU-238	1-5	5.226E+02	1.777E+02	8.246E-05	2.299E+02	1.150E+02	1.714E+00	3.041E+01	4.515E+01	5.383E-01	1.672E+00
PU-238	6-8	5.715E-01	1.921E-01	9.623E-03	2.544E-01	9.827E-04	2.383E-03	3.316E-02	5.208E-02	7.765E-04	3.254E-03
PU-238	9-10	2.241E-02	7.619E-03	3.536E-09	9.859E-03	4.930E-03	7.350E-05	1.304E-03	1.936E-03	2.308E-05	7.170E-05
PU-238	11-12	4.432E-01	1.479E-01	1.731E-01	1.989E-01	3.474E-05	1.457E-03	2.578E-02	4.259E-02	4.483E-04	1.401E-03
PU-238	13-15	3.347E+02	1.138E+02	5.281E-05	1.472E+02	7.362E+01	1.098E+00	1.948E+01	2.891E+01	3.447E-01	1.071E+00
PU-238	16	1.647E-02	1.427E-02	3.949E-03	1.734E-03	5.810E-03	3.208E-03	2.308E-03	2.168E-02	1.214E-03	8.604E-03
PU-238	17-21	4.238E+04	1.420E+04	1.337E+04	1.895E+04	1.799E+03	1.393E+02	2.465E+03	3.993E+03	4.302E+01	1.343E+02
PU-238	22	1.647E-02	1.427E-02	3.949E-03	1.734E-03	5.810E-03	3.208E-03	2.308E-03	2.168E-02	1.214E-03	8.604E-03
PU-238	23-24	4.432E-01	1.479E-01	1.731E-01	1.989E-01	3.474E-05	1.457E-03	2.578E-02	4.259E-02	4.483E-04	1.401E-03
PU-238	25-27	3.347E+02	1.138E+02	5.281E-05	1.472E+02	7.362E+01	1.098E+00	1.948E+01	2.891E+01	3.447E-01	1.071E+00
PU-238	28	1.647E-02	1.427E-02	3.949E-03	1.734E-03	5.810E-03	3.208E-03	2.308E-03	2.168E-02	1.214E-03	8.604E-03
PU-238	29 -30	1.092E+00	3.711E-01	1.722E-07	4.803E-01	2.401E-01	3.580E-03	6.353E-02	9.431E-02	1.124E-03	3.493E-03
PU-239	1-5	8.480E+02	2.827E+02	9.060E-05	3.719E+02	1.467E+02	2.752E+00	4.790E+01	7.171E+01	8.554E-01	2.678E+00
PU-239	6-8	6.401E-01	2.144E-01	8.765E-03	2.804E-01	4.142E-04	2.472E-03	3.668E-02	5.531E-02	7.671E-04	2.745E-03
PU-239	9-10	2.554E-02	8.515E-03	2.729E-09	1.120E-02	4.419E-03	8.291E-05	1.443E-03	2.160E-03	2.577E-05	8.067E-05
PU-239	11-12	5.110E-01	1.703E-01	1.647E-01	2.264E-01	3.239E-05	1.681E-03	2.914E-02	4.819E-02	5.043E-04	1.625E-03
PU-239	13-15	6.135E+02	2.045E+02	6.555E-05	2.691E+02	1.061E+02	1.991E+00	3.466E+01	5.188E+01	6.189E-01	1.938E+00
PU-239	16	8.137E-03	7.137E-03	2.161E-03	1.187E-03	2.401E-03	2.395E-03	1.554E-03	9.138E-03	7.370E-04	3.869E-03
PU-239	17-21	5.442E+04	1.814E+04	1.272E+04	2.404E+04	2.592E+03	1.784E+02	3.095E+03	4.986E+03	5.403E+01	1.727E+02
PU-239	22	8.137E-03	7.137E-03	2.161E-03	1.187E-03	2.401E-03	2.395E-03	1.554E-03	9.138E-03	7.370E-04	3.869E-03
PU-239	23-24	5.110E-01	1.703E-01	1.647E-01	2.264E-01	3.239E-05	1.681E-03	2.914E-02	4.819E-02	5.043E-04	1.625E-03
PU-239	25-27	6.135E+02	2.045E+02	6.555E-05	2.691E+02	1.061E+02	1.991E+00	3.466E+01	5.188E+01	6.189E-01	1.938E+00
PU-239	28	8.137E-03	7.137E-03	2.161E-03	1.187E-03	2.401E-03	2.395E-03	1.554E-03	9.138E-03	7.370E-04	3.869E-03
PU-239	29 -30	1.244E+00	4.148E-01	1.329E-07	5.458E-01	2.153E-01	4.039E-03	7.029E-02	1.052E-01	1.255E-03	3.930E-03

		ORGAN									
NUCLIDE	PATHWAYS SUMMED	BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
PU-240	1-5	8.109E+02	2.703E+02	1.184E-04	3.557E+02	1.413E+02	2.618E+00	4.581E+01	6.871E+01	8.180E-01	2.561E+00
PU-240	6-8	6.413E-01	2.151E-01	9.312E-03	2.833E-01	8.796E-04	2.621E-03	3.681E-02	5.752E-02	8.399E-04	3.367E-03
PU-240	9-10	2.554E-02	8.515E-03	3.729E-09	1.120E-02	4.450E-03	8.246E-05	1.443E-03	2.165E-03	2.577E-05	8.067E-05
PU-240	11-12	5.116E-01	1.703E-01	1.653E-01	2.269E-01	3.261E-05	1.681E-03	2.914E-02	4.819E-02	5.043E-04	1.625E-03
PU-240	13-15	5.795E+02	1.932E+02	8.458E-05	2.542E+02	1.009E+02	1.871E+00	3.273E+01	4.910E+01	5.845E-01	1.830E+00
PU-240	16	1.501E-02	1.307E-02	3.762E-03	1.814E-03	5.196E-03	3.288E-03	2.314E-03	1.901E-02	1.174E-03	7.604E-03
PU-240	17-21	5.363E+04	1.786E+04	1.276E+04	2.372E+04	2.465E+03	1.754E+02	3.048E+03	4.918E+03	5.319E+01	1.701E+02
PU-240	22	1.501E-02	1.307E-02	3.762E-03	1.814E-03	5.196E-03	3.288E-03	2.314E-03	1.901E-02	1.174E-03	7.604E-03
PU-240	23-24	5.116E-01	1.703E-01	1.653E-01	2.269E-01	3.261E-05	1.681E-03	2.914E-02	4.819E-02	5.043E-04	1.625E-03
PU-240	25-27	5.795E+02	1.932E+02	8.458E-05	2.542E+02	1.009E+02	1.871E+00	3.273E+01	4.910E+01	5.845E-01	1.830E+00
PU-240	28	1.501E-02	1.307E-02	3.762E-03	1.814E-03	5.196E-03	3.288E-03	2.314E-03	1.901E-02	1.174E-03	7.604E-03
PU-240	29 -30	1.244E+00	4.148E-01	1.816E-07	5.458E-01	2.168E-01	4.017E-03	7.029E-02	1.054E-01	1.255E-03	3.930E-03
AM-241	1-5	2.025E+04	6.820E+03	1.353E-01	9.058E+03	1.172E+02	6.735E+01	1.172E+03	1.705E+03	2.099E+01	6.394E+01
AM-241	6-8	8.161E-01	3.637E-01	6.782E-02	3.395E-01	3.289E-02	8.223E-02	8.852E-02	1.390E-01	2.533E-02	3.858E-02
AM-241	9-10	8.093E+00	2.726E+00	5.409E-05	3.620E+00	4.685E-02	2.692E-02	4.685E-01	6.815E-01	8.391E-03	2.556E-02
AM-241	11-12	5.284E-01	1.759E-01	1.754E-01	2.348E-01	3.654E-05	1.737E-03	3.026E-02	4.987E-02	5.323E-04	1.681E-03
AM-241	13-15	1.497E+04	5.041E+03	1.000E-01	6.696E+03	8.665E+01	4.978E+01	8.665E+02	1.260E+03	1.552E+01	4.726E+01
AM-241	16	9.471E-01	8.671E-01	3.535E-01	2.888E-01	1.974E-01	4.809E-01	3.062E-01	5.002E-01	1.481E-01	2.191E-01
AM-241	17-21	4.059E+05	1.366E+05	1.354E+04	1.815E+05	2.117E+03	1.349E+03	2.347E+04	3.460E+04	4.197E+02	1.283E+03
AM-241	22	9.471E-01	8.671E-01	3.535E-01	2.888E-01	1.974E-01	4.809E-01	3.062E-01	5.002E-01	1.481E-01	2.191E-01
AM-241	23-24	5.284E-01	1.759E-01	1.754E-01	2.348E-01	3.654E-05	1.737E-03	3.026E-02	4.987E-02	5.323E-04	1.681E-03
AM-241	25-27	1.497E+04	5.041E+03	1.000E-01	6.696E+03	8.665E+01	4.978E+01	8.665E+02	1.260E+03	1.552E+01	4.726E+01
AM-241	28	9.471E-01	8.671E-01	3.535E-01	2.888E-01	1.974E-01	4.809E-01	3.062E-01	5.002E-01	1.481E-01	2.191E-01
AM-241	29 -30	3.942E+02	1.328E+02	2.635E-03	1.764E+02	2.282E+00	1.311E+00	2.282E+01	3.320E+01	4.087E-01	1.245E+00
PU-242	1-5	8.155E+02	2.718E+02	2.416E-04	3.624E+02	1.420E+02	2.658E+00	4.621E+01	6.947E+01	8.230E-01	2.582E+00
PU-242	6-8	6.102E-01	2.042E-01	8.639E-03	2.680E-01	8.089E-04	2.375E-03	3.475E-02	5.457E-02	7.813E-04	3.166E-03
PU-242	9-10	2.420E-02	8.067E-03	7.170E-09	1.076E-02	4.213E-03	7.887E-05	1.371E-03	2.061E-03	2.442E-05	7.663E-05
PU-242	11-12	4.869E-01	1.619E-01	1.569E-01	2.157E-01	3.088E-05	1.569E-03	2.802E-02	4.595E-02	5.043E-04	1.541E-03
PU-242	13-15	5.924E+02	1.975E+02	1.755E-04	2.633E+02	1.031E+02	1.931E+00	3.357E+01	5.047E+01	5.979E-01	1.876E+00
PU-242	16	1.354E-02	1.167E-02	3.088E-03	1.227E-03	4.776E-03	2.314E-03	1.728E-03	1.814E-02	9.905E-04	7.237E-03
PU-242	17-21	5.204E+04	1.732E+04	1.211E+04	2.308E+04	2.518E+03	1.682E+02	2.982E+03	4.778E+03	5.352E+01	1.647E+02
PU-242	22	1.354E-02	1.167E-02	3.088E-03	1.227E-03	4.776E-03	2.314E-03	1.728E-03	1.814E-02	9.905E-04	7.237E-03
PU-242	23-24	4.869E-01	1.619E-01	1.569E-01	2.157E-01	3.088E-05	1.569E-03	2.802E-02	4.595E-02	5.043E-04	1.541E-03
PU-242	25-27	5.924E+02	1.975E+02	1.755E-04	2.633E+02	1.031E+02	1.931E+00	3.357E+01	5.047E+01	5.979E-01	1.876E+00
PU-242	28	1.354E-02	1.167E-02	3.088E-03	1.227E-03	4.776E-03	2.314E-03	1.728E-03	1.814E-02	9.905E-04	7.237E-03
PU-242	29 -30	1.179E+00	3.930E-01	3.493E-07	5.239E-01	2.052E-01	3.842E-03	6.680E-02	1.004E-01	1.190E-03	3.733E-03

NUCLIDE	PATHWAYS SUMMED	ORGAN									
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
AM-243	1-5	2.805E+04	4.724E+04	1.423E+00	1.255E+04	2.200E+02	9.360E+01	1.624E+03	2.362E+03	3.004E+01	8.858E+01
AM-243	6-8	1.243E+00	1.626E+00	3.008E-01	5.424E-01	1.788E-01	3.642E-01	2.830E-01	4.056E-01	9.229E-02	1.953E-01
AM-243	9-10	8.093E+00	1.363E+01	4.106E-04	3.620E+00	6.346E-02	2.700E-02	4.685E-01	6.815E-01	8.668E-03	2.556E-02
AM-243	11-12	5.284E-01	8.741E-01	1.698E-01	2.359E-01	1.805E-04	1.737E-03	3.026E-02	4.987E-02	5.324E-04	1.681E-03
AM-243	13-15	2.214E+04	3.730E+04	1.124E+00	9.907E+03	1.737E+02	7.389E+01	1.282E+03	1.865E+03	2.372E+01	6.993E+01
AM-243	16	3.528E+00	3.255E+00	1.754E+00	1.507E+00	1.074E+00	2.174E+00	1.474E+00	2.101E+00	5.503E-01	1.161E+00
AM-243	17-21	5.810E+05	9.773E+05	1.313E+04	2.599E+05	4.250E+03	1.937E+03	3.361E+04	4.934E+04	6.197E+02	1.836E+03
AM-243	22	3.528E+00	3.255E+00	1.754E+00	1.507E+00	1.074E+00	2.174E+00	1.474E+00	2.101E+00	5.503E-01	1.161E+00
AM-243	23-24	5.284E-01	8.741E-01	1.698E-01	2.359E-01	1.805E-04	1.737E-03	3.026E-02	4.987E-02	5.324E-04	1.681E-03
AM-243	25-27	2.214E+04	3.730E+04	1.124E+00	9.907E+03	1.737E+02	7.389E+01	1.282E+03	1.865E+03	2.372E+01	6.993E+01
AM-243	28	3.528E+00	3.255E+00	1.754E+00	1.507E+00	1.074E+00	2.174E+00	1.474E+00	2.101E+00	5.503E-01	1.161E+00
AM-243	29 -30	3.942E+02	6.639E+02	2.000E-02	1.764E+02	3.091E+00	1.315E+00	2.282E+01	3.320E+01	4.222E-01	1.245E+00

INTERIM FACTORS FOR POPULATION FATAL CANCERS AS A FUNCTION OF NUCLIDE

NUCLIDE	PATHWAYS SUMMED											
	1-5	6-8	9-10	11-12	13-15	16	17-21	22	23-24	25-27	28	29 -30
C-14	4.577E-02	7.300E-13	9.547E-10	1.460E-12	4.092E-02	0.0	1.917E-04	0.0	1.848E-06	1.899E-04	0.0	1.918E-04
NI-59	6.800E-04	2.199E-10	4.690E-07	4.438E-10	5.303E-04	0.0	1.297E-02	0.0	4.438E-10	5.303E-04	0.0	2.285E-05
SR-90	1.214E-01	2.641E-08	1.035E-07	2.124E-07	1.039E-01	0.0	2.552E+00	0.0	2.124E-07	1.039E-01	0.0	5.043 -06
ZR-93	1.361E-03	3.973E-05	4.020E-08	1.562E-09	1.141E-03	2.386E-04	2.795E-02	2.386E-04	1.562E-09	1.141E-03	2.386E-04	1.958E-06
TC-99	2.850E-04	6.195E-10	7.137E-09	1.239E-09	2.366E-04	0.0	5.868E-03	0.0	1.239E-09	2.366E-04	0.0	3.476E-07
SN-126	1.747E-02	4.665E-04	5.454E-08	3.420E-08	8.225E-03	2.802E-03	2.033E-01	2.802E-03	3.420E-08	8.225E-03	2.802E-03	2.657E-06
I-129	1.073E-02	1.103E-05	6.594E-07	2.923E-09	8.230E-03	6.626E-05	2.010E-01	6.626E-05	2.923E-09	8.230E-03	6.626E-05	3.212E-05
CS-135	3.813E-03	2.425E-10	1.081E-07	4.851E-10	3.067E-03	0.0	7.486E-02	0.0	4.851E-10	3.067E-03	0.0	5.265E-06
CS-137	1.382E-02	1.503E-04	8.529E-07	3.832E-09	9.529E-03	9.024E-04	2.328E-01	9.024E-04	3.832E-09	9.529E-03	9.024E-04	4.155E-05
SM-151	1.167E-04	7.791E-09	5.071E-08	1.618E-09	8.436E-05	4.486E-08	2.183E-03	4.486E-08	1.618E-09	8.436E-05	4.486E-08	2.470E-06
RA-226	3.110E+00	4.760E-04	2.010E-04	8.992E-07	2.588E+00	2.856E-03	6.320E+01	2.856E-03	8.992E-07	2.588E+00	2.856E-03	9.790E-03
U-234	1.331E+00	1.445E-06	9.533E-06	6.643E-06	1.156E+00	4.917E-06	2.870E+01	4.917E-06	6.643E-06	1.156E+00	4.917E-06	4.644E-04
NP-237	5.928E-01	1.265E-04	1.675E-05	2.419E-05	4.239E-01	6.286E-04	1.221E+01	6.286E-04	2.419E-05	4.239E-01	6.286E-04	8.159E-04
PU-238	2.040E-02	2.033E-05	8.746E-07	2.251E-05	1.306E-02	2.571E-06	2.056E+00	2.571E-06	2.251E-05	1.306E-02	2.571E-06	4.261E-05
PU-239	3.194E-02	2.238E-05	9.622E-07	2.444E-05	2.311E-02	1.171E-06	2.451E+00	1.171E-06	2.444E-05	2.311E-02	1.171E-06	4.687E-05
PU-240	3.057E-02	2.264E-05	9.631E-07	2.448E-05	2.185E-02	2.303E-06	2.423E+00	2.303E-06	2.448E-05	2.185E-02	2.303E-06	4.692E-05
AM-241	6.993E-01	4.018E-05	2.795E-04	2.548E-05	5.170E-01	1.037E-04	1.458E+01	1.037E-04	2.548E-05	5.170E-01	1.037E-04	1.362E-02
PU-242	3.082E-02	2.148E-05	9.146E-07	2.328E-05	2.239E-02	2.123E-06	2.343E+00	2.123E-06	2.328E-05	2.239E-02	2.123E-06	4.455E-05
AM-243	2.482E+00	1.301E-04	7.160E-04	5.320E-05	1.959E+00	4.362E-04	5.191E+01	4.362E-04	5.320E-05	1.959E+00	4.362E-04	3.488E-02

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                    INTERIM FACTORS FOR POPULATION GENETIC EFFECTS TO FIRST GENERATION AS A FUNCTION OF NUCLIDE

NUCLIDE  ************************************************************PATHWAYS SUMMED****************************************************
             1-5       6-8       9-10      11-12      13-15       16         17-21        22         23-24      25-27       28         29 -30
  C-14    1.813E-03 3.001E-14 3.783E-11 6.001E-14 1.621E-03 0.0         7.599E-06 0.0         7.596E-08 7.523E-06 0.0         7.599E-06
 NI-59    5.360E-05 1.205E-11 3.697E-08 2.409E-11 4.180E-05 0.0         1.021E-03 0.0         2.409E-11 4.180E-05 0.0         1.801E-06
 SR-90    3.642E-04 8.629E-11 3.106E-10 4.186E-11 3.118E-04 0.0         7.610E-03 0.0         4.186E-11 3.118E-04 0.0         1.513E-08
 ZR-93    5.246E-05 3.954E-06 1.549E-09 6.651E-12 4.397E-05 2.375E-05 1.073E-03 2.375E-05 6.651E-12 4.397E-05 2.375E-05 7.547E-08
 TC-99    1.500E-05 1.188E-12 3.757E-10 2.376E-12 1.246E-05 0.0         3.040E-04 0.0         2.376E-12 1.246E-05 0.0         1.830E-08
 SN-126   1.405E-04 4.642E-05 4.387E-10 8.438E-11 6.615E-05 2.788E-04 1.620E-03 2.788E-04 8.438E-11 6.615E-05 2.788E-04 2.137E-08
 I-129    1.524E-05 1.102E-06 9.370E-10 4.229E-12 1.170E-05 6.617E-06 2.857E-04 6.617E-06 4.229E-12 1.170E-05 6.617E-06 4.565E-08
 CS-135   6.732E-04 4.186E-11 1.908E-08 8.372E-11 5.416E-04 0.0         1.322E-02 0.0         8.372E-11 5.416E-04 0.0         9.295E-07
 CS-137   1.963E-03 1.115E-05 1.211E-07 5.327E-10 1.353E-03 6.697E-05 3.306E-02 6.697E-05 5.327E-10 1.353E-03 6.697E-05 5.901E-06
 SM-151   6.073E-08 8.930E-10 2.639E-11 1.424E-13 4.390E-08 5.360E-09 1.082E-06 5.360E-09 1.424E-13 4.390E-08 5.360E-09 1.286E-09
 RA-226   3.684E-02 3.909E-05 2.381E-06 3.824E-09 3.066E-02 2.348E-04 7.481E-01 2.348E-04 3.824E-09 3.066E-02 2.348E-04 1.160E-04
 U-234    4.200E-02 6.805E-08 3.007E-07 6.612E-09 3.646E-02 3.515E-07 8.898E-01 3.515E-07 6.612E-09 3.646E-02 3.515E-07 1.465E-05
 NP-237   1.459E-03 8.515E-06 4.122E-08 4.259E-08 1.043E-03 5.083E-05 2.874E-02 5.083E-05 4.259E-08 1.043E-03 5.083E-05 2.008E-06
 PU-238   4.421E-05 8.060E-08 1.896E-09 3.698E-08 2.831E-05 1.964E-07 3.546E-03 1.964E-07 3.698E-08 2.831E-05 1.964E-07 9.234E-08
 PU-239   7.066E-05 7.025E-08 2.129E-09 4.259E-08 5.113E-05 9.211E-08 4.535E-03 9.211E-08 4.259E-08 5.113E-05 9.211E-08 1.037E-07
 PU-240   6.758E-05 8.414E-08 2.129E-09 4.259E-08 4.829E-05 1.756E-07 4.466E-03 1.756E-07 4.259E-08 4.829E-05 1.756E-07 1.037E-07
 AM-241   1.699E-03 1.278E-06 6.789E-07 4.427E-08 1.256E-03 7.344E-06 3.405E-02 7.344E-06 4.427E-08 1.256E-03 7.344E-06 3.307E-05
 PU-242   6.811E-05 7.895E-08 2.021E-09 4.091E-08 4.948E-05 1.645E-07 4.365E-03 1.645E-07 4.091E-08 4.948E-05 1.645E-07 9.846E-08
 AM-243   2.372E-03 5.753E-06 6.845E-07 4.427E-08 1.873E-03 3.422E-05 4.911E-02 3.422E-05 4.427E-08 1.873E-03 3.422E-05 3.334E-05
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INTERIM FACTORS FOR POPULATION HEALTH EFFECTS AS A FUNCTION OF NUCLIDE, PATHWAY, AND ORGAN

NUCLIDE	PATHWAY		*******FATAL CANCERS******* ORGAN								FIRST GENERATION ***GENETIC EFFECTS***	
			BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
C-14	1	7.40E-05	2.35E-06	2.72E-05	6.83E-06	2.47E-06	5.87E-06	1.79E-07	2.13E-06	2.70E-05	1.48E-06	1.45E-06
C-14	2	5.59E-04	1.77E-05	2.05E-04	5.15E-05	1.87E-05	4.43E-05	1.35E-06	1.61E-05	2.04E-04	1.12E-05	1.10E-05
C-14	3	2.99E-02	9.51E-04	1.10E-02	2.76E-03	9.99E-04	2.37E-03	7.22E-05	8.61E-04	1.09E-02	5.98E-04	5.87E-04
C-14	4	1.11E-02	3.53E-04	4.08E-03	1.03E-03	3.71E-04	8.81E-04	2.68E-05	3.20E-04	4.06E-03	2.22E-04	2.18E-04
C-14	5	4.10E-03	1.30E-04	1.50E-03	3.78E-04	1.37E-04	3.25E-04	9.89E-06	1.18E-04	1.50E-03	8.19E-05	8.05E-05
C-14	6	7.30E-13	2.37E-14	2.71E-13	6.93E-14	2.49E-14	4.05E-14	1.82E-15	2.22E-14	2.77E-13	1.48E-14	1.52E-14
C-14	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C-14	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C-14	9	8.18E-10	2.60E-11	3.00E-10	7.55E-11	2.73E-11	6.49E-11	1.98E-12	2.36E-11	2.99E-10	1.64E-11	1.61E-11
C-14	10	1.36E-10	4.33E-12	5.01E-11	1.26E-11	4.56E-12	1.08E-11	3.29E-13	3.93E-12	4.98E-11	2.73E-12	2.68E-12
C-14	11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C-14	12	1.46E-12	4.74E-14	5.42E-13	1.39E-13	4.98E-14	8.09E-14	3.63E-15	4.44E-14	5.53E-13	2.96E-14	3.04E-14
C-14	13	2.75E-02	8.75E-04	1.01E-02	2.54E-03	9.19E-04	2.18E-03	6.65E-05	7.92E-04	1.00E-02	5.50E-04	5.40E-04
C-14	14	9.78E-03	3.11E-04	3.59E-03	9.02E-04	3.27E-04	7.76E-04	2.36E-05	2.82E-04	3.57E-03	1.96E-04	1.92E-04
C-14	15	3.61E-03	1.15E-04	1.32E-03	3.33E-04	1.20E-04	2.86E-04	8.71E-06	1.04E-04	1.32E-03	7.21E-05	7.08E-05
C-14	16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C-14	17	1.85E-06	6.00E-08	6.87E-07	1.75E-07	6.30E-08	1.02E-07	4.60E-09	5.62E-08	7.00E-07	3.75E-08	3.84E-08
C-14	18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C-14	19	1.90E-04	6.03E-06	6.97E-05	1.75E-05	6.34E-06	1.51E-05	4.58E-07	5.47E-06	6.93E-05	3.80E-06	3.73E-06
C-14	20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C-14	21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C-14	22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C-14	23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C-14	24	1.85E-06	6.00E-08	6.87E-07	1.75E-07	6.30E-08	1.02E-07	4.60E-09	5.62E-08	7.00E-07	3.75E-08	3.84E-08
C-14	25	1.90E-04	6.03E-06	6.97E-05	1.75E-05	6.34E-06	1.51E-05	4.58E-07	5.47E-06	6.93E-05	3.80E-06	3.73E-06
C-14	26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C-14	27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C-14	28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C-14	29	1.92E-04	6.09E-06	7.04E-05	1.77E-05	6.41E-06	1.52E-05	4.63E-07	5.52E-06	7.00E-05	3.83E-06	3.77E-06
C-14	30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

					ORGAN						FIRST GENERATION	
NUCLIDE	PATHWAY	****************FATAL CANCERS				*****************************					***GENETIC EFFECTS***	
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN		OVARIES	TESTES
NI-59	1	8.21E-05	1.94E-05	1.29E-05	1.29E-05	6.67E-06	3.90E-06	3.24E-07	3.24E-06	2.27E-05	3.24E-06	3.24E-06
NI-59	2	1.36E-05	3.22E-06	2.15E-06	2.15E-06	1.11E-06	6.47E-07	5.37E-08	5.37E-07	3.76E-06	5.37E-07	5.37E-07
NI-59	3	4.03E-04	9.55E-05	6.36E-05	6.36E-05	3.28E-05	1.92E-05	1.59E-06	1.59E-05	1.11E-04	1.59E-05	1.59E-05
NI-59	4	9.80E-05	2.32E-05	1.55E-05	1.55E-05	7.97E-06	4.66E-06	3.86E-07	3.86E-06	2.70E-05	3.86E-06	3.86E-06
NI-59	5	8.28E-05	1.96E-05	1.31E-05	1.31E-05	6.73E-06	3.93E-06	3.26E-07	3.26E-06	2.28E-05	3.26E-06	3.26E-06
NI-59	6	2.20E-10	3.61E-11	2.41E-11	9.49E-11	1.40E-11	1.99E-12	6.02E-13	6.02E-12	4.22E-11	6.02E-12	6.02E-12
NI-59	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NI-59	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NI-59	9	4.54E-07	1.07E-07	7.16E-08	7.16E-08	3.69E-08	2.16E-08	1.79E-09	1.79E-08	1.25E-07	1.79E-08	1.79E-08
NI-59	10	1.51E-08	3.58E-09	2.39E-09	2.39E-09	1.23E-09	7.19E-10	5.96E-11	5.96E-10	4.17E-09	5.96E-10	5.96E-10
NI-59	11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NI-59	12	4.44E-10	7.23E-11	4.82E-11	1.90E-10	2.79E-11	7.98E-12	1.20E-12	1.20E-11	8.43E-11	1.20E-11	1.20E-11
NI-59	13	3.71E-04	8.79E-05	5.85E-05	5.85E-05	3.02E-05	1.76E-05	1.46E-06	1.46E-05	1.02E-04	1.46E-05	1.46E-05
NI-59	14	8.63E-05	2.04E-05	1.36E-05	1.36E-05	7.01E-06	4.10E-06	3.40E-07	3.40E-06	2.38E-05	3.40E-06	3.40E-06
NI-59	15	7.29E-05	1.72E-05	1.15E-05	1.15E-05	5.92E-06	3.46E-06	2.87E-07	2.87E-06	2.01E-05	2.87E-06	2.87E-06
NI-59	16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NI-59	17	3.43E-05	5.58E-06	3.72E-06	1.47E-05	2.16E-06	6.16E-07	9.30E-08	9.30E-07	6.51E-06	9.30E-07	9.30E-07
NI-59	18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NI-59	19	9.05E-03	2.14E-03	1.43E-03	1.43E-03	7.36E-04	4.30E-04	3.57E-05	3.57E-04	2.50E-03	3.57E-04	3.57E-04
NI-59	20	2.10E-03	4.98E-04	3.32E-04	3.32E-04	1.71E-04	1.00E-04	8.30E-06	8.30E-05	5.81E-04	8.30E-05	8.30E-05
NI-59	21	1.78E-03	4.21E-04	2.80E-04	2.80E-04	1.44E-04	8.44E-05	7.00E-06	7.00E-05	4.90E-04	7.00E-05	7.00E-05
NI-59	22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NI-59	23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NI-59	24	4.44E-10	7.23E-11	4.82E-11	1.90E-10	2.79E-11	7.98E-12	1.20E-12	1.20E-11	8.43E-11	1.20E-11	1.20E-11
NI-59	25	3.71E-04	8.79E-05	5.85E-05	5.85E-05	3.02E-05	1.76E-05	1.46E-06	1.46E-05	1.02E-04	1.46E-05	1.46E-05
NI-59	26	8.63E-05	2.04E-05	1.36E-05	1.36E-05	7.01E-06	4.10E-06	3.40E-07	3.40E-06	2.38E-05	3.40E-06	3.40E-06
NI-59	27	7.29E-05	1.72E-05	1.15E-05	1.15E-05	5.92E-06	3.46E-06	2.87E-07	2.87E-06	2.01E-05	2.87E-06	2.87E-06
NI-59	28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NI-59	29	2.21E-05	5.23E-06	3.49E-06	3.49E-06	1.80E-06	1.05E-06	8.71E-08	8.71E-07	6.10E-06	8.71E-07	8.71E-07
NI-59	30	7.37E-07	1.74E-07	1.16E-07	1.16E-07	5.99E-08	3.50E-08	2.90E-09	2.90E-08	2.03E-07	2.90E-08	2.90E-08

ORGAN

NUCLIDE	PATHWAY	FATAL CANCERS								FIRST GENERATION ***GENETIC EFFECTS***	
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
SR-90	1	8.03E-03	2.41E-03	3.46E-03	1.26E-10	1.15E-05	7.96E-04	1.20E-06	1.20E-05	1.34E-03	1.20E-05	1.20E-05
SR-90	2	6.66E-05	2.00E-05	2.87E-05	1.05E-12	9.52E-08	6.60E-06	9.98E-09	9.98E-08	1.11E-05	9.98E-08	9.98E-08
SR-90	3	1.05E-01	3.17E-02	4.54E-02	1.66E-09	1.51E-04	1.05E-02	1.58E-05	1.58E-04	1.76E-02	1.58E-04	1.58E-04
SR-90	4	7.79E-03	2.34E-03	3.35E-03	1.22E-10	1.11E-05	7.72E-04	1.17E-06	1.17E-05	1.30E-03	1.17E-05	1.17E-05
SR-90	5	1.04E-04	3.12E-05	4.47E-05	1.63E-12	1.48E-07	1.03E-05	1.56E-08	1.56E-07	1.73E-05	1.56E-07	1.56E-07
SR-90	6	2.64E-08	8.41E-09	1.23E-08	5.51E-10	4.17E-11	3.08E-10	4.31E-12	4.31E-11	4.73E-09	4.31E-11	4.31E-11
SR-90	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SR-90	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SR-90	9	8.87E-08	2.67E-08	3.82E-08	1.40E-15	1.27E-10	8.80E-09	1.33E-11	1.33E-10	1.48E-08	1.33E-10	1.33E-10
SR-90	10	1.48E-08	4.44E-09	6.37E-09	2.33E-16	2.11E-11	1.47E-09	2.22E-12	2.22E-11	2.46E-09	2.22E-11	2.22E-11
SR-90	11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SR-90	12	2.12E-07	1.80E-09	2.71E-09	1.91E-07	1.08E-10	1.04E-08	2.10E-12	2.10E-11	5.92E-09	2.10E-11	2.09E-11
SR-90	13	9.70E-02	2.91E-02	4.18E-02	1.53E-09	1.39E-04	9.62E-03	1.45E-05	1.45E-04	1.62E-02	1.45E-04	1.45E-04
SR-90	14	6.85E-03	2.06E-03	2.95E-03	1.08E-10	9.80E-06	6.80E-04	1.03E-06	1.03E-05	1.14E-03	1.03E-05	1.03E-05
SR-90	15	9.12E-05	2.74E-05	3.93E-05	1.43E-12	1.30E-07	9.05E-06	1.37E-08	1.37E-07	1.52E-05	1.37E-07	1.37E-07
SR-90	16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SR-90	17	1.64E-02	1.39E-04	2.09E-04	1.48E-02	8.35E-06	8.05E-04	1.62E-07	1.62E-06	4.57E-04	1.62E-06	1.61E-06
SR-90	18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SR-90	19	2.37E+00	7.11E-01	1.02E+00	3.72E-08	3.38E-03	2.35E-01	3.55E-04	3.55E-03	3.94E-01	3.55E-03	3.55E-03
SR-90	20	1.67E-01	5.02E-02	7.20E-02	2.63E-09	2.39E-04	1.66E-02	2.51E-05	2.51E-04	2.78E-02	2.51E-04	2.51E-04
SR-90	21	2.23E-03	6.69E-04	9.59E-04	3.50E-11	3.18E-06	2.21E-04	3.34E-07	3.34E-06	3.71E-04	3.34E-06	3.34E-06
SR-90	22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SR-90	23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SR-90	24	2.12E-07	1.80E-09	2.71E-09	1.91E-07	1.08E-10	1.04E-08	2.10E-12	2.10E-11	5.92E-09	2.10E-11	2.09E-11
SR-90	25	9.70E-02	2.91E-02	4.18E-02	1.53E-09	1.39E-04	9.62E-03	1.45E-05	1.45E-04	1.62E-02	1.45E-04	1.45E-04
SR-90	26	6.85E-03	2.06E-03	2.95E-03	1.08E-10	9.80E-06	6.80E-04	1.03E-06	1.03E-05	1.14E-03	1.03E-05	1.03E-05
SR-90	27	9.12E-05	2.74E-05	3.93E-05	1.43E-12	1.30E-07	9.05E-06	1.37E-08	1.37E-07	1.52E-05	1.37E-07	1.37E-07
SR-90	28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SR-90	29	4.32E-06	1.30E-06	1.86E-06	6.80E-14	6.18E-09	4.29E-07	6.48E-10	6.48E-09	7.20E-07	6.48E-09	6.48E-09
SR-90	30	7.20E-07	2.17E-07	3.10E-07	1.13E-14	1.03E-09	7.14E-08	1.08E-10	1.08E-09	1.20E-07	1.08E-09	1.08E-09

NUCLIDE	PATHWAY	ORGAN FATAL CANCERS								FIRST GENERATION ***GENETIC EFFECTS***	
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
ZR-93	1	7.79E-05	3.96E-07	2.69E-06	3.14E-07	2.87E-07	7.03E-05	3.40E-09	4.00E-07	3.48E-06	2.73E-06	2.69E-07
ZR-93	2	4.30E-07	2.19E-09	1.48E-08	1.73E-09	1.59E-09	3.88E-07	1.88E-11	2.21E-09	1.92E-08	1.51E-08	1.49E-09
ZR-93	3	3.01E-04	1.53E-06	1.04E-05	1.21E-06	1.11E-06	2.72E-04	1.31E-08	1.55E-06	1.34E-05	1.06E-05	1.04E-06
ZR-93	4	9.39E-04	4.77E-06	3.24E-05	3.78E-06	3.46E-06	8.48E-04	4.09E-08	4.82E-06	4.19E-05	3.29E-05	3.25E-06
ZR-93	5	4.24E-05	2.16E-07	1.46E-06	1.71E-07	1.57E-07	3.83E-05	1.85E-09	2.18E-07	1.89E-06	1.49E-06	1.47E-07
ZR-93	6	4.75E-10	1.15E-11	2.76E-11	3.45E-10	5.91E-12	3.91E-11	3.70E-13	3.70E-12	4.18E-11	4.09E-12	1.39E-12
ZR-93	7	3.97E-05	1.98E-06	7.91E-06	7.91E-06	1.98E-06	3.95E-06	1.98E-07	1.98E-06	1.38E-05	1.98E-06	1.98E-06
ZR-93	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZR-93	9	2.58E-08	1.31E-10	8.91E-10	1.04E-10	9.53E-11	2.33E-08	1.13E-12	1.33E-10	1.15E-09	9.07E-10	8.93E-11
ZR-93	10	1.44E-08	7.30E-11	4.95E-10	5.78E-11	5.30E-11	1.30E-08	6.26E-13	7.37E-11	6.40E-10	5.04E-10	4.96E-11
ZR-93	11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZR-93	12	1.56E-09	8.24E-12	3.92E-11	1.31E-09	1.64E-11	8.02E-11	8.97E-13	7.62E-12	9.81E-11	5.83E-12	8.24E-13
ZR-93	13	2.77E-04	1.41E-06	9.56E-06	1.12E-06	1.02E-06	2.50E-04	1.21E-08	1.42E-06	1.24E-05	9.73E-06	9.59E-07
ZR-93	14	8.26E-04	4.20E-06	2.85E-05	3.33E-06	3.05E-06	7.46E-04	3.60E-08	4.24E-06	3.69E-05	2.90E-05	2.86E-06
ZR-93	15	3.73E-05	1.90E-07	1.29E-06	1.50E-07	1.38E-07	3.37E-05	1.63E-09	1.92E-07	1.67E-06	1.31E-06	1.29E-07
ZR-93	16	2.39E-04	1.19E-05	4.75E-05	4.75E-05	1.19E-05	2.37E-05	1.19E-06	1.19E-05	8.31E-05	1.19E-05	1.19E-05
ZR-93	17	1.21E-04	6.36E-07	3.03E-06	1.01E-04	1.27E-06	6.19E-06	6.92E-08	5.88E-07	7.57E-06	4.50E-07	6.36E-08
ZR-93	18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZR-93	19	6.76E-03	3.44E-05	2.33E-04	2.72E-05	2.50E-05	6.11E-03	2.95E-07	3.47E-05	3.02E-04	2.37E-04	2.34E-05
ZR-93	20	2.02E-02	1.02E-04	6.95E-04	8.11E-05	7.44E-05	1.82E-02	8.79E-07	1.03E-04	8.99E-04	7.07E-04	6.97E-05
ZR-93	21	9.11E-04	4.63E-06	3.14E-05	3.67E-06	3.36E-06	8.22E-04	3.97E-08	4.68E-06	4.06E-05	3.20E-05	3.15E-06
ZR-93	22	2.39E-04	1.19E-05	4.75E-05	4.75E-05	1.19E-05	2.37E-05	1.19E-06	1.19E-05	8.31E-05	1.19E-05	1.19E-05
ZR-93	23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZR-93	24	1.56E-09	8.24E-12	3.92E-11	1.31E-09	1.64E-11	8.02E-11	8.97E-13	7.62E-12	9.81E-11	5.83E-12	8.24E-13
ZR-93	25	2.77E-04	1.41E-06	9.56E-06	1.12E-06	1.02E-06	2.50E-04	1.21E-08	1.42E-06	1.24E-05	9.73E-06	9.59E-07
ZR-93	26	8.26E-04	4.20E-06	2.85E-05	3.33E-06	3.05E-06	7.46E-04	3.60E-08	4.24E-06	3.69E-05	2.90E-05	2.86E-06
ZR-93	27	3.73E-05	1.90E-07	1.29E-06	1.50E-07	1.38E-07	3.37E-05	1.63E-09	1.92E-07	1.67E-06	1.31E-06	1.29E-07
ZR-93	28	2.39E-04	1.19E-05	4.75E-05	4.75E-05	1.19E-05	2.37E-05	1.19E-06	1.19E-05	8.31E-05	1.19E-05	1.19E-05
ZR-93	29	1.26E-06	6.40E-09	4.34E-08	5.07E-09	4.64E-09	1.14E-06	5.49E-11	6.46E-09	5.62E-08	4.42E-08	4.35E-09
ZR-93	30	6.99E-07	3.55E-09	2.41E-08	2.81E-09	2.58E-09	6.31E-07	3.05E-11	3.59E-09	3.12E-08	2.45E-08	2.42E-09

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                                                           ORGAN
NUCLIDE  PATHWAY********************************FATAL CANCERS********************************************     FIRST GENERATION
                  BONE     RED MARROW     LUNGS     LIVER      GI-LLI     THYROID    KIDNEYS  OTHERORGAN     ***GENETIC EFFECTS***
                                                                WALL                                          OVARIES     TESTES

 TC-99      1   2.42E-05  7.26E-07  2.59E-06  0.0        1.26E-06  1.29E-05  2.83E-06  9.21E-07  3.01E-06    6.37E-07  6.37E-07
 TC-99      2   6.02E-07  1.80E-08  6.44E-08  0.0        3.14E-08  3.20E-07  7.05E-08  2.29E-08  7.49E-08    1.58E-08  1.58E-08
 TC-99      3   1.92E-04  5.75E-06  2.05E-05  0.0        1.00E-05  1.02E-04  2.25E-05  7.29E-06  2.39E-05    5.05E-06  5.05E-06
 TC-99      4   6.25E-05  1.87E-06  6.69E-06  0.0        3.26E-06  3.32E-05  7.32E-06  2.38E-06  7.78E-06    1.65E-06  1.65E-06
 TC-99      5   5.82E-06  1.74E-07  6.22E-07  0.0        3.03E-07  3.09E-06  6.81E-07  2.21E-07  7.24E-07    1.53E-07  1.53E-07
 TC-99      6   6.19E-10  6.78E-13  2.41E-12  5.85E-10  1.18E-12  9.30E-12  2.65E-12  8.60E-13  1.74E-11    5.94E-13  5.94E-13
 TC-99      7   0.0       0.0       0.0       0.0        0.0       0.0       0.0       0.0       0.0         0.0       0.0
 TC-99      8   0.0       0.0       0.0       0.0        0.0       0.0       0.0       0.0       0.0         0.0       0.0
 TC-99      9   2.68E-09  8.02E-11  2.86E-10  0.0        1.40E-10  1.42E-09  3.13E-10  1.02E-10  3.33E-10    7.04E-11  7.04E-11
 TC-99     10   4.46E-09  1.34E-10  4.77E-10  0.0        2.33E-10  2.37E-09  5.22E-10  1.70E-10  5.55E-10    1.17E-10  1.17E-10
 TC-99     11   0.0       0.0       0.0       0.0        0.0       0.0       0.0       0.0       0.0         0.0       0.0
 TC-99     12   1.24E-09  1.36E-12  4.82E-12  1.17E-09  2.36E-12  1.86E-11  5.30E-12  1.72E-12  3.48E-11    1.19E-12  1.19E-12
 TC-99     13   1.76E-04  5.29E-06  1.89E-05  0.0        9.20E-06  9.38E-05  2.07E-05  6.71E-06  2.19E-05    4.64E-06  4.64E-06
 TC-99     14   5.50E-05  1.65E-06  5.89E-06  0.0        2.87E-06  2.93E-05  6.44E-06  2.09E-06  6.85E-06    1.45E-06  1.45E-06
 TC-99     15   5.12E-06  1.53E-07  5.47E-07  0.0        2.67E-07  2.72E-06  5.99E-07  1.95E-07  6.37E-07    1.35E-07  1.35E-07
 TC-99     16   0.0       0.0       0.0       0.0        0.0       0.0       0.0       0.0       0.0         0.0       0.0
 TC-99     17   9.56E-05  1.05E-07  3.72E-07  9.03E-05  1.82E-07  1.44E-06  4.09E-07  1.33E-07  2.69E-06    9.17E-08  9.17E-08
 TC-99     18   0.0       0.0       0.0       0.0        0.0       0.0       0.0       0.0       0.0         0.0       0.0
 TC-99     19   4.30E-03  1.29E-04  4.60E-04  0.0        2.24E-04  2.29E-03  5.04E-04  1.64E-04  5.35E-04    1.13E-04  1.13E-04
 TC-99     20   1.34E-03  4.03E-05  1.44E-04  0.0        7.00E-05  7.14E-04  1.57E-04  5.11E-05  1.67E-04    3.53E-05  3.53E-05
 TC-99     21   1.25E-04  3.74E-06  1.34E-05  0.0        6.51E-06  6.64E-05  1.46E-05  4.75E-06  1.55E-05    3.29E-06  3.29E-06
 TC-99     22   0.0       0.0       0.0       0.0        0.0       0.0       0.0       0.0       0.0         0.0       0.0
 TC-99     23   0.0       0.0       0.0       0.0        0.0       0.0       0.0       0.0       0.0         0.0       0.0
 TC-99     24   1.24E-09  1.36E-12  4.82E-12  1.17E-09  2.36E-12  1.86E-11  5.30E-12  1.72E-12  3.48E-11    1.19E-12  1.19E-12
 TC-99     25   1.76E-04  5.29E-06  1.89E-05  0.0        9.20E-06  9.38E-05  2.07E-05  6.71E-06  2.19E-05    4.64E-06  4.64E-06
 TC-99     26   5.50E-05  1.65E-06  5.89E-06  0.0        2.87E-06  2.93E-05  6.44E-06  2.09E-06  6.85E-06    1.45E-06  1.45E-06
 TC-99     27   5.12E-06  1.53E-07  5.47E-07  0.0        2.67E-07  2.72E-06  5.99E-07  1.95E-07  6.37E-07    1.35E-07  1.35E-07
 TC-99     28   0.0       0.0       0.0       0.0        0.0       0.0       0.0       0.0       0.0         0.0       0.0
 TC-99     29   1.30E-07  3.91E-09  1.39E-08  0.0        6.80E-09  6.93E-08  1.53E-08  4.96E-09  1.62E-08    3.43E-09  3.43E-09
 TC-99     30   2.17E-07  6.51E-09  2.32E-08  0.0        1.13E-08  1.15E-07  2.54E-08  8.26E-09  2.70E-08    5.72E-09  5.72E-09
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NUCLIDE	PATHWAY	ORGAN ***************FATAL CANCERS***************								FIRST GENERATION ***GENETIC EFFECTS***	
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
SN-126	1	1.41E-03	1.72E-04	6.89E-04	2.50E-05	3.40E-06	4.74E-04	1.00E-07	5.69E-06	3.97E-05	5.67E-06	5.67E-06
SN-126	2	7.01E-03	8.57E-04	3.43E-03	1.24E-04	1.69E-05	2.36E-03	4.99E-07	2.83E-05	1.97E-04	2.82E-05	2.82E-05
SN-126	3	6.66E-03	8.14E-04	3.26E-03	1.18E-04	1.61E-05	2.24E-03	4.74E-07	2.69E-05	1.88E-04	2.68E-05	2.68E-05
SN-126	4	2.95E-04	3.60E-05	1.44E-04	5.22E-06	7.10E-07	9.91E-05	2.10E-08	1.19E-06	8.29E-06	1.18E-06	1.18E-06
SN-126	5	2.09E-03	2.55E-04	1.02E-03	3.70E-05	5.03E-06	7.03E-04	1.49E-07	8.42E-06	5.88E-05	8.39E-06	8.39E-06
SN-126	6	1.70E-08	4.43E-10	1.77E-09	1.42E-08	1.17E-11	4.26E-10	3.45E-13	1.73E-11	1.21E-10	1.73E-11	1.73E-11
SN-126	7	4.67E-04	2.32E-05	9.28E-05	9.28E-05	2.32E-05	4.64E-05	2.32E-06	2.32E-05	1.62E-04	2.32E-05	2.32E-05
SN-126	8	2.57E-11	1.28E-12	5.11E-12	5.11E-12	1.28E-12	2.55E-12	1.28E-13	1.28E-12	8.94E-12	1.28E-12	1.28E-12
SN-126	9	4.67E-08	5.71E-09	2.29E-08	8.29E-10	1.13E-10	1.57E-08	3.33E-12	1.89E-10	1.32E-09	1.88E-10	1.88E-10
SN-126	10	7.79E-09	9.52E-10	3.81E-09	1.38E-10	1.88E-11	2.62E-09	5.54E-13	3.14E-11	2.19E-10	3.13E-11	3.13E-11
SN-126	11	1.54E-10	7.67E-12	3.07E-11	3.07E-11	7.67E-12	1.53E-11	7.67E-13	7.67E-12	5.37E-11	7.67E-12	7.67E-12
SN-126	12	3.40E-08	8.85E-10	3.54E-09	2.85E-08	2.35E-11	8.52E-10	6.89E-13	3.45E-11	2.42E-10	3.45E-11	3.45E-11
SN-126	13	6.13E-03	7.49E-04	3.00E-03	1.09E-04	1.48E-05	2.06E-03	4.36E-07	2.47E-05	1.73E-04	2.46E-05	2.46E-05
SN-126	14	2.59E-04	3.17E-05	1.27E-04	4.60E-06	6.25E-07	8.72E-05	1.84E-08	1.05E-06	7.30E-06	1.04E-06	1.04E-06
SN-126	15	1.84E-03	2.24E-04	8.98E-04	3.26E-05	4.43E-06	6.18E-04	1.31E-07	7.41E-06	5.17E-05	7.39E-06	7.39E-06
SN-126	16	2.80E-03	1.39E-04	5.58E-04	5.58E-04	1.39E-04	2.79E-04	1.39E-05	1.39E-04	9.76E-04	1.39E-04	1.39E-04
SN-126	17	2.63E-03	6.83E-05	2.73E-04	2.20E-03	1.81E-06	6.58E-05	5.32E-08	2.66E-06	1.87E-05	2.66E-06	2.66E-06
SN-126	18	1.19E-05	5.92E-07	2.37E-06	2.37E-06	5.92E-07	1.18E-06	5.92E-08	5.92E-07	4.15E-06	5.92E-07	5.92E-07
SN-126	19	1.50E-01	1.83E-02	7.31E-02	2.65E-03	3.60E-04	5.03E-02	1.06E-05	6.03E-04	4.21E-03	6.01E-04	6.01E-04
SN-126	20	6.32E-03	7.73E-04	3.09E-03	1.12E-04	1.52E-05	2.13E-03	4.50E-07	2.55E-05	1.78E-04	2.54E-05	2.54E-05
SN-126	21	4.48E-02	5.48E-03	2.19E-02	7.95E-04	1.08E-04	1.51E-02	3.19E-06	1.81E-04	1.26E-03	1.80E-04	1.80E-04
SN-126	22	2.80E-03	1.39E-04	5.58E-04	5.58E-04	1.39E-04	2.79E-04	1.39E-05	1.39E-04	9.76E-04	1.39E-04	1.39E-04
SN-126	23	1.54E-10	7.67E-12	3.07E-11	3.07E-11	7.67E-12	1.53E-11	7.67E-13	7.67E-12	5.37E-11	7.67E-12	7.67E-12
SN-126	24	3.40E-08	8.85E-10	3.54E-09	2.85E-08	2.35E-11	8.52E-10	6.89E-13	3.45E-11	2.42E-10	3.45E-11	3.45E-11
SN-126	25	6.13E-03	7.49E-04	3.00E-03	1.09E-04	1.48E-05	2.06E-03	4.36E-07	2.47E-05	1.73E-04	2.46E-05	2.46E-05
SN-126	26	2.59E-04	3.17E-05	1.27E-04	4.60E-06	6.25E-07	8.72E-05	1.84E-08	1.05E-06	7.30E-06	1.04E-06	1.04E-06
SN-126	27	1.84E-03	2.24E-04	8.98E-04	3.26E-05	4.43E-06	6.18E-04	1.31E-07	7.41E-06	5.17E-05	7.39E-06	7.39E-06
SN-126	28	2.80E-03	1.39E-04	5.58E-04	5.58E-04	1.39E-04	2.79E-04	1.39E-05	1.39E-04	9.76E-04	1.39E-04	1.39E-04
SN-126	29	2.28E-06	2.78E-07	1.11E-06	4.04E-08	5.49E-09	7.66E-07	1.62E-10	9.19E-09	6.41E-08	9.16E-09	9.16E-09
SN-126	30	3.80E-07	4.64E-08	1.86E-07	6.73E-09	9.15E-10	1.28E-07	2.70E-11	1.53E-09	1.07E-08	1.53E-09	1.53E-09

NUCLIDE	PATHWAY	ORGAN ********************************FATAL CANCERS**									FIRST GENERATION ***GENETIC EFFECTS***	
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL		THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
I-129	1	1.63E-03	1.81E-06	7.57E-06	1.44E-06	1.46E-06	2.69E-07	1.57E-03	1.41E-06	4.47E-05	1.19E-06	1.12E-06
I-129	2	4.05E-05	4.51E-08	1.88E-07	3.58E-08	3.62E-08	6.70E-09	3.90E-05	3.51E-08	1.11E-06	2.96E-08	2.79E-08
I-129	3	6.43E-03	7.17E-06	3.00E-05	5.69E-06	5.76E-06	1.07E-06	6.20E-03	5.58E-06	1.77E-04	4.71E-06	4.44E-06
I-129	4	2.44E-03	2.72E-06	1.14E-05	2.16E-06	2.19E-06	4.05E-07	2.35E-03	2.12E-06	6.72E-05	1.79E-06	1.68E-06
I-129	5	1.84E-04	2.05E-07	8.58E-07	1.63E-07	1.65E-07	3.05E-08	1.78E-04	1.60E-07	5.07E-06	1.35E-07	1.27E-07
I-129	6	1.46E-09	1.62E-12	6.78E-12	8.83E-12	1.31E-12	2.40E-13	1.40E-09	1.26E-12	4.02E-11	1.06E-12	1.00E-12
I-129	7	1.10E-05	9.70E-07	3.50E-06	1.29E-06	2.40E-07	1.53E-07	6.71E-08	3.59E-07	4.45E-06	2.27E-07	8.75E-07
I-129	8	1.84E-13	1.61E-14	5.82E-14	2.15E-14	4.00E-15	2.55E-15	1.12E-15	5.97E-15	7.42E-14	3.78E-15	1.45E-14
I-129	9	3.60E-07	4.01E-10	1.67E-09	3.18E-10	3.22E-10	5.96E-11	3.47E-07	3.12E-10	9.89E-09	2.63E-10	2.48E-10
I-129	10	3.00E-07	3.34E-10	1.40E-09	2.65E-10	2.68E-10	4.96E-11	2.89E-07	2.60E-10	8.24E-09	2.19E-10	2.07E-10
I-129	11	1.10E-12	9.67E-14	3.50E-13	1.29E-13	2.40E-14	1.53E-14	6.74E-15	3.59E-14	4.45E-13	2.27E-14	8.74E-14
I-129	12	2.92E-09	3.24E-12	1.36E-11	1.77E-11	2.61E-12	4.80E-13	2.80E-09	2.52E-12	8.04E-11	2.12E-12	2.00E-12
I-129	13	5.92E-03	6.60E-06	2.76E-05	5.24E-06	5.30E-06	9.80E-07	5.70E-03	5.13E-06	1.63E-04	4.33E-06	4.08E-06
I-129	14	2.15E-03	2.40E-06	1.00E-05	1.90E-06	1.92E-06	3.56E-07	2.07E-03	1.86E-06	5.91E-05	1.57E-06	1.48E-06
I-129	15	1.62E-04	1.81E-07	7.55E-07	1.43E-07	1.45E-07	2.68E-08	1.56E-04	1.41E-07	4.46E-06	1.19E-07	1.12E-07
I-129	16	6.63E-05	5.82E-06	2.10E-05	7.76E-06	1.44E-06	9.20E-07	4.03E-07	2.15E-06	2.68E-05	1.36E-06	5.26E-06
I-129	17	2.26E-04	2.50E-07	1.05E-06	1.36E-06	2.02E-07	3.70E-08	2.16E-04	1.94E-07	6.21E-06	1.64E-07	1.54E-07
I-129	18	8.52E-08	7.47E-09	2.70E-08	9.99E-09	1.85E-09	1.18E-09	5.20E-10	2.77E-09	3.44E-08	1.75E-09	6.75E-09
I-129	19	1.44E-01	1.61E-04	6.72E-04	1.28E-04	1.29E-04	2.39E-05	1.39E-01	1.25E-04	3.97E-03	1.06E-04	9.96E-05
I-129	20	5.24E-02	5.85E-05	2.44E-04	4.64E-05	4.69E-05	8.68E-06	5.05E-02	4.55E-05	1.44E-03	3.84E-05	3.62E-05
I-129	21	3.95E-03	4.41E-06	1.84E-05	3.50E-06	3.54E-06	6.55E-07	3.81E-03	3.43E-06	1.09E-04	2.89E-06	2.73E-06
I-129	22	6.63E-05	5.82E-06	2.10E-05	7.76E-06	1.44E-06	9.20E-07	4.03E-07	2.15E-06	2.68E-05	1.36E-06	5.26E-06
I-129	23	1.10E-12	9.67E-14	3.50E-13	1.29E-13	2.40E-14	1.53E-14	6.74E-15	3.59E-14	4.45E-13	2.27E-14	8.74E-14
I-129	24	2.92E-09	3.24E-12	1.36E-11	1.77E-11	2.61E-12	4.80E-13	2.80E-09	2.52E-12	8.04E-11	2.12E-12	2.00E-12
I-129	25	5.92E-03	6.60E-06	2.76E-05	5.24E-06	5.30E-06	9.80E-07	5.70E-03	5.13E-06	1.63E-04	4.33E-06	4.08E-06
I-129	26	2.15E-03	2.40E-06	1.00E-05	1.90E-06	1.92E-06	3.56E-07	2.07E-03	1.86E-06	5.91E-05	1.57E-06	1.48E-06
I-129	27	1.62E-04	1.81E-07	7.55E-07	1.43E-07	1.45E-07	2.68E-08	1.56E-04	1.41E-07	4.46E-06	1.19E-07	1.12E-07
I-129	28	6.63E-05	5.82E-06	2.10E-05	7.76E-06	1.44E-06	9.20E-07	4.03E-07	2.15E-06	2.68E-05	1.36E-06	5.26E-06
I-129	29	1.75E-05	1.95E-08	8.16E-08	1.55E-08	1.57E-08	2.90E-09	1.69E-05	1.52E-08	4.82E-07	1.28E-08	1.21E-08
I-129	30	1.46E-05	1.63E-08	6.80E-08	1.29E-08	1.31E-08	2.42E-09	1.41E-05	1.27E-08	4.02E-07	1.07E-08	1.01E-08

NUCLIDE	PATHWAY	FATAL CANCERS BONE	RED MARROW	LUNGS	LIVER	ORGAN GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	FIRST GENERATION ***GENETIC EFFECTS*** OVARIES	TESTES
CS-135	1	2.55E-04	2.25E-05	9.00E-05	0.0	2.25E-05	2.15E-06	2.27E-06	2.25E-05	9.30E-05	2.25E-05	2.25E-05
CS-135	2	1.69E-04	1.49E-05	5.97E-05	0.0	1.49E-05	1.43E-06	1.51E-06	1.49E-05	6.17E-05	1.49E-05	1.49E-05
CS-135	3	2.13E-03	1.88E-04	7.50E-04	0.0	1.88E-04	1.79E-05	1.89E-05	1.88E-04	7.75E-04	1.88E-04	1.88E-04
CS-135	4	9.99E-04	8.82E-05	3.53E-04	0.0	8.82E-05	8.43E-06	8.90E-06	8.82E-05	3.64E-04	8.82E-05	8.82E-05
CS-135	5	2.65E-04	2.34E-05	9.35E-05	0.0	2.34E-05	2.23E-06	2.36E-06	2.34E-05	9.66E-05	2.34E-05	2.34E-05
CS-135	6	2.43E-10	2.09E-11	8.37E-11	7.17E-12	2.09E-11	4.77E-13	2.10E-12	2.09E-11	8.63E-11	2.09E-11	2.09E-11
CS-135	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CS-135	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CS-135	9	8.46E-08	7.47E-09	2.99E-08	0.0	7.47E-09	7.13E-10	7.53E-10	7.47E-09	3.08E-08	7.47E-09	7.47E-09
CS-135	10	2.35E-08	2.07E-09	8.30E-09	0.0	2.07E-09	1.98E-10	2.09E-10	2.07E-09	8.57E-09	2.07E-09	2.07E-09
CS-135	11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CS-135	12	4.85E-10	4.19E-11	1.67E-10	1.43E-11	4.19E-11	9.54E-13	4.19E-12	4.19E-11	1.73E-10	4.19E-11	4.19E-11
CS-135	13	1.96E-03	1.73E-04	6.90E-04	0.0	1.73E-04	1.65E-05	1.74E-05	1.73E-04	7.13E-04	1.73E-04	1.73E-04
CS-135	14	8.79E-04	7.76E-05	3.10E-04	0.0	7.76E-05	7.42E-06	7.83E-06	7.76E-05	3.21E-04	7.76E-05	7.76E-05
CS-135	15	2.33E-04	2.06E-05	8.23E-05	0.0	2.06E-05	1.97E-06	2.08E-06	2.06E-05	8.50E-05	2.06E-05	2.06E-05
CS-135	16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CS-135	17	3.74E-05	3.23E-06	1.29E-05	1.11E-06	3.23E-06	7.36E-08	3.24E-07	3.23E-06	1.33E-05	3.23E-06	3.23E-06
CS-135	18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CS-135	19	4.77E-02	4.21E-03	1.68E-02	0.0	4.21E-03	4.02E-04	4.25E-04	4.21E-03	1.74E-02	4.21E-03	4.21E-03
CS-135	20	2.14E-02	1.89E-03	7.57E-03	0.0	1.89E-03	1.81E-04	1.91E-04	1.89E-03	7.82E-03	1.89E-03	1.89E-03
CS-135	21	5.68E-03	5.02E-04	2.01E-03	0.0	5.02E-04	4.79E-05	5.06E-05	5.02E-04	2.07E-03	5.02E-04	5.02E-04
CS-135	22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CS-135	23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CS-135	24	4.85E-10	4.19E-11	1.67E-10	1.43E-11	4.19E-11	9.54E-13	4.19E-12	4.19E-11	1.73E-10	4.19E-11	4.19E-11
CS-135	25	1.96E-03	1.73E-04	6.90E-04	0.0	1.73E-04	1.65E-05	1.74E-05	1.73E-04	7.13E-04	1.73E-04	1.73E-04
CS-135	26	8.79E-04	7.76E-05	3.10E-04	0.0	7.76E-05	7.42E-06	7.83E-06	7.76E-05	3.21E-04	7.76E-05	7.76E-05
CS-135	27	2.33E-04	2.06E-05	8.23E-05	0.0	2.06E-05	1.97E-06	2.08E-06	2.06E-05	8.50E-05	2.06E-05	2.06E-05
CS-135	28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CS-135	29	4.12E-06	3.64E-07	1.45E-06	0.0	3.64E-07	3.47E-08	3.67E-08	3.64E-07	1.50E-06	3.64E-07	3.64E-07
CS-135	30	1.14E-06	1.01E-07	4.04E-07	0.0	1.01E-07	9.65E-09	1.02E-08	1.01E-07	4.17E-07	1.01E-07	1.01E-07

		ORGAN									
		******************************FATAL CANCERS***************************************								FIRST GENERATION ***GENETIC EFFECTS***	
NUCLIDE	PATHWAY	BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
CS-137	1	2.01E-03	1.37E-04	5.93E-04	1.60E-04	1.58E-04	1.04E-04	1.35E-05	1.[illegible]5E-04	6.91E-04	1.52E-04	1.34E-04
CS-137	2	1.33E-03	9.09E-05	3.94E-04	1.06E-04	1.05E-04	6.91E-05	8.96E-06	1.03E-04	4.58E-04	1.01E-04	8.91E-05
CS-137	3	7.83E-03	5.34E-04	2.31E-03	6.23E-04	6.16E-04	4.05E-04	5.26E-05	6.05E-04	2.69E-03	5.90E-04	5.23E-04
CS-137	4	2.08E-03	1.42E-04	6.14E-04	1.66E-04	1.64E-04	1.08E-04	1.40E-05	1.61E-04	7.15E-04	1.57E-04	1.39E-04
CS-137	5	5.55E-04	3.78E-05	1.64E-04	4.41E-05	4.36E-05	2.87E-05	3.72E-06	4.28E-05	1.90E-04	4.18E-05	3.70E-05
CS-137	6	1.89E-09	1.27E-10	5.50E-10	1.82E-10	1.47E-10	8.97E-11	1.25E-11	1.44E-10	6.39E-10	1.40E-10	1.24E-10
CS-137	7	1.50E-04	9.21E-06	3.52E-05	2.84E-05	6.27E-06	1.09E-05	7.94E-07	6.70E-06	5.28E-05	2.77E-06	8.38E-06
CS-137	8	8.44E-12	5.18E-13	1.98E-12	1.60E-12	3.53E-13	6.11E-13	4.46E-14	3.75E-13	2.96E-12	1.54E-13	4.71E-13
CS-137	9	6.67E-07	4.55E-08	1.97E-07	5.31E-08	5.25E-08	3.45E-08	4.48E-09	5.15E-08	2.29E-07	5.03E-08	4.45E-08
CS-137	10	1.85E-07	1.26E-08	5.47E-08	1.47E-08	1.46E-08	9.59E-09	1.24E-09	1.43E-08	6.36E-08	1.40E-08	1.24E-08
CS-137	11	5.07E-11	3.11E-12	1.19E-11	9.60E-12	2.12E-12	3.67E-12	2.68E-13	2.25E-12	1.78E-11	9.27E-13	2.83E-12
CS-137	12	3.78E-09	2.54E-10	1.10E-09	3.63E-10	2.93E-10	1.79E-10	2.50E-11	2.87E-10	1.28E-09	2.80E-10	2.49E-10
CS-137	13	7.21E-03	4.91E-04	2.13E-03	5.73E-04	5.67E-04	3.73E-04	4.84E-05	5.56E-04	2.47E-03	5.43E-04	4.81E-04
CS-137	14	1.83E-03	1.25E-04	5.41E-04	1.46E-04	1.44E-04	9.49E-05	1.23E-05	[illegible].42E-04	6.29E-04	1.38E-04	1.22E-04
CS-137	15	4.88E-04	3.32E-05	1.44E-04	3.88E-05	3.84E-05	2.52E-05	3.28E-06	3.77E-05	1.68E-04	3.68E-05	3.26E-05
CS-137	16	9.02E-04	5.53E-05	2.11E-04	1.71E-04	3.77E-05	6.54E-05	4.77E-06	4.02E-05	3.17E-04	1.66E-05	5.04E-05
CS-137	17	2.92E-04	1.96E-05	8.50E-05	2.80E-05	2.26E-05	1.38E-05	1.93E-06	2.22E-05	9.87E-05	2.16E-05	1.92E-05
CS-137	18	3.91E-06	2.40E-07	9.17E-07	7.41E-07	1.64E-07	2.83E-07	2.07E-08	1.74E-07	1.37E-06	7.16E-08	2.18E-07
CS-137	19	1.76E-01	1.20E-02	5.18E-02	1.40E-02	1.38E-02	9.10E-03	1.18E-03	1.36E-02	6.04E-02	1.32E-02	1.17E-02
CS-137	20	4.47E-02	3.05E-03	1.32E-02	3.56E-03	3.52E-03	2.31E-03	3.00E-04	3.45E-03	1.54E-02	3.37E-03	2.98E-03
CS-137	21	1.19E-02	8.11E-04	3.51E-03	9.46E-04	9.36E-04	6.16E-04	7.99E-05	9.19E-04	4.09E-03	8.97E-04	7.94E-04
CS-137	22	9.02E-04	5.53E-05	2.11E-04	1.71E-04	3.77E-05	6.54E-05	4.77E-06	4.02E-05	3.17E-04	1.66E-05	5.04E-05
CS-137	23	5.07E-11	3.11E-12	1.19E-11	9.60E-12	2.12E-12	3.67E-12	2.68E-13	2.25E-12	1.78E-11	9.27E-13	2.83E-12
CS-137	24	3.78E-09	2.54E-10	1.10E-09	3.63E-10	2.93E-10	1.79E-10	2.50E-11	2.87E-10	1.28E-09	2.80E-10	2.49E-10
CS-137	25	7.21E-03	4.91E-04	2.13E-03	5.73E-04	5.67E-04	3.73E-04	4.84E-05	5.56E-04	2.47E-03	5.43E-04	4.81E-04
CS-137	26	1.83E-03	1.25E-04	5.41E-04	1.46E-04	1.44E-04	9.49E-05	1.23E-05	1.42E-04	6.29E-04	1.38E-04	1.22E-04
CS-137	27	4.88E-04	3.32E-05	1.44E-04	3.88E-05	3.84E-05	2.52E-05	3.28E-06	3.77E-05	1.68E-04	3.68E-05	3.26E-05
CS-137	28	9.02E-04	5.53E-05	2.11E-04	1.71E-04	3.77E-05	6.54E-05	4.77E-06	4.02E-05	3.17E-04	1.66E-05	5.04E-05
CS-137	29	3.25E-05	2.21E-06	9.59E-06	2.59E-06	2.56E-06	1.68E-06	2.18E-07	2.51E-06	1.12E-05	2.45E-06	2.17E-06
CS-137	30	9.03E-06	6.15E-07	2.66E-06	7.18E-07	7.10E-07	4.67E-07	6.06E-08	6.97E-07	3.10E-06	6.80E-07	6.03E-07

NUCLIDE	PATHWAY	ORGAN *****FATAL CANCERS*****									FIRST GENERATION ***GENETIC EFFECTS***	
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL		THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
SM-151	1	2.39E-05	9.87E-09	2.57E-08	8.44E-10	3.48E-08	2.35E-05	2.07E-11	1.11E-08	3.29E-07	1.14E-08	1.08E-09
SM-151	2	9.92E-07	4.09E-10	1.07E-09	3.50E-11	1.44E-09	9.75E-07	8.58E-13	4.60E-10	1.36E-08	4.72E-10	4.47E-11
SM-151	3	8.99E-05	3.71E-08	9.66E-08	3.17E-09	1.31E-07	8.83E-05	7.78E-11	4.17E-08	1.24E-06	4.27E-08	4.05E-09
SM-151	4	1.77E-08	7.28E-12	1.90E-11	6.23E-13	2.57E-11	1.74E-08	1.53E-14	8.19E-12	2.43E-10	8.39E-12	7.95E-13
SM-151	5	1.87E-06	7.73E-10	2.02E-09	6.61E-11	2.72E-09	1.84E-06	1.62E-12	8.69E-10	2.58E-08	8.91E-10	8.44E-11
SM-151	6	3.21E-10	1.38E-11	2.17E-11	1.78E-10	5.30E-11	1.57E-11	2.91E-14	1.51E-11	2.33E-11	3.05E-13	2.89E-13
SM-151	7	7.47E-09	5.10E-10	1.78E-09	3.54E-10	4.90E-11	1.22E-10	1.89E-11	1.47E-10	4.49E-09	8.17E-11	8.11E-10
SM-151	8	3.97E-17	2.71E-18	9.46E-18	1.88E-18	2.61E-19	6.49E-19	1.01E-19	7.80E-19	2.39E-17	4.35E-19	4.31E-18
SM-151	9	6.61E-09	2.73E-12	7.11E-12	2.33E-13	9.61E-12	6.50E-09	5.72E-15	3.07E-12	9.10E-11	3.14E-12	2.98E-13
SM-151	10	4.41E-08	1.82E-11	4.74E-11	1.56E-12	6.41E-11	4.33E-08	3.81E-14	2.04E-11	6.07E-10	2.10E-11	1.99E-12
SM-151	11	2.39E-16	1.63E-17	5.68E-17	1.13E-17	1.57E-18	3.90E-18	6.04E-19	4.68E-18	1.43E-16	2.61E-18	2.59E-17
SM-151	12	1.62E-09	2.86E-12	4.68E-12	1.52E-09	1.06E-11	3.41E-11	1.08E-14	3.10E-12	4.28E-11	8.24E-14	6.00E-14
SM-151	13	8.27E-05	3.41E-08	8.89E-08	2.92E-09	1.20E-07	8.13E-05	7.15E-11	3.83E-08	1.14E-06	3.93E-08	3.72E-09
SM-151	14	1.55E-08	6.41E-12	1.67E-11	5.48E-13	2.26E-11	1.53E-08	1.34E-14	7.20E-12	2.14E-10	7.39E-12	7.00E-13
SM-151	15	1.65E-06	6.81E-10	1.77E-09	5.82E-11	2.40E-09	1.62E-06	1.4[illegible]E-12	7.65E-10	2.27E-08	7.84E-10	7.43E-11
SM-151	16	4.49E-08	3.06E-09	1.07E-08	2.12E-09	2.94E-10	7.31E-10	1.13E-10	8.80E-10	2.70E-08	4.91E-10	4.87E-09
SM-151	17	1.25E-04	2.21E-07	3.62E-07	1.17E-04	8.22E-07	2.63E-06	8.31E-10	2.40E-07	3.30E-06	6.36E-09	4.63E-09
SM-151	18	1.84E-11	1.26E-12	4.39E-12	8.73E-13	1.21E-13	3.01E-13	4.67E-14	3.61E-13	1.11E-11	2.02E-13	2.00E-12
SM-151	19	2.02E-03	8.32E-07	2.17E-06	7.12E-08	2.93E-06	1.98E-03	1.75E-09	9.35E-07	2.78E-05	9.59E-07	9.08E-08
SM-151	20	3.79E-07	1.56E-10	4.08E-10	1.34E-11	5.51E-10	3.73E-07	3.28E-13	1.76E-10	5.22E-09	1.80E-10	1.71E-11
SM-151	21	4.03E-05	1.66E-08	4.33E-08	1.42E-09	5.85E-08	3.96E-05	3.48E-11	1.87E-08	5.54E-07	1.91E-08	1.81E-09
SM-151	22	4.49E-08	3.06E-09	1.07E-08	2.12E-09	2.94E-10	7.31E-10	1.13E-10	8.80E-10	2.70E-08	4.91E-10	4.87E-09
SM-151	23	2.39E-16	1.63E-17	5.68E-17	1.13E-17	1.57E-18	3.90E-18	6.04E-19	4.68E-18	1.43E-16	2.61E-18	2.59E-17
SM-151	24	1.62E-09	2.86E-12	4.68E-12	1.52E-09	1.06E-11	3.41E-11	1.08E-14	3.10E-12	4.28E-11	8.24E-14	6.00E-14
SM-151	25	8.27E-05	3.41E-08	8.89E-08	2.92E-09	1.20E-07	8.13E-05	7.15E-11	3.83E-08	1.14E-06	3.93E-08	3.72E-09
SM-151	26	1.55E-08	6.41E-12	1.67E-11	5.48E-13	2.26E-11	1.53E-08	1.34E-14	7.20E-12	2.14E-10	7.39E-12	7.00E-13
SM-151	27	1.65E-06	6.81E-10	1.77E-09	5.82E-11	2.40E-09	1.62E-06	1.43E-12	7.65E-10	2.27E-08	7.84E-10	7.43E-11
SM-151	28	4.49E-08	3.06E-09	1.07E-08	2.12E-09	2.94E-10	7.31E-10	1.13E-10	8.80E-10	2.70E-08	4.91E-10	4.87E-09
SM-151	29	3.22E-07	1.33E-10	3.46E-10	1.14E-11	4.68E-10	3.17E-07	2.79E-13	1.49E-10	4.43E-09	1.53E-10	1.45E-11
SM-151	30	2.15E-06	8.86E-10	2.31E-09	7.58E-11	3.12E-09	2.11E-06	1.86E-12	9.96E-10	2.96E-08	1.02E-09	9.67E-11

NUCLIDE	PATHWAY	ORGAN FATAL CANCERS									FIRST GENERATION GENETIC EFFECTS	
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL		THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
RA-226	1	2.73E-01	1.27E-01	1.72E-02	2.18E-06	3.76E-03	3.28E-03	1.61E-04	1.16E-02	1.10E-01	1.62E-03	1.61E-03
RA-226	2	2.26E-02	1.05E-02	1.43E-03	1.81E-07	3.12E-04	2.72E-04	1.33E-05	9.65E-04	9.09E-03	1.34E-04	1.33E-04
RA-226	3	2.78E+00	1.29E+00	1.75E-01	2.22E-05	3.83E-02	3.34E-02	1.64E-03	1.19E-01	1.12E+00	1.65E-02	1.64E-02
RA-226	4	3.38E-02	1.58E-02	2.13E-03	2.70E-07	4.66E-04	4.07E-04	2.00E-05	1.44E-03	1.36E-02	2.01E-04	2.00E-04
RA-226	5	3.03E-03	1.41E-03	1.91E-04	2.42E-08	4.17E-05	3.64E-05	1.79E-06	1.29E-04	1.22E-03	1.80E-05	1.79E-05
RA-226	6	4.50E-07	3.08E-08	1.10E-08	3.15E-07	9.53E-10	5.60E-10	9.53E-11	9.78E-10	9.02E-08	9.53E-10	9.53E-10
RA-226	7	4.76E-04	2.80E-05	1.04E-04	9.20E-05	2.05E-05	3.75E-05	2.35E-06	1.94E-05	1.72E-04	1.81E-05	2.10E-05
RA-226	8	2.75E-11	1.67E-12	6.17E-12	5.64E-12	1.24E-12	2.29E-12	1.42E-13	1.18E-12	9.17E-12	1.10E-12	1.25E-12
RA-226	9	1.51E-04	7.02E-05	9.51E-06	1.20E-09	2.08E-06	1.81E-06	8.90E-08	6.43E-06	6.06E-05	8.96E-07	8.90E-07
RA-226	10	5.02E-05	2.34E-05	3.17E-06	4.01E-10	6.93E-07	6.04E-07	2.97E-08	2.14E-06	2.02E-05	2.99E-07	2.97E-07
RA-226	11	1.65E-10	1.00E-11	3.71E-11	3.39E-11	7.47E-12	1.37E-11	8.54E-13	7.07E-12	5.51E-11	6.60E-12	7.54E-12
RA-226	12	8.99E-07	6.16E-08	2.20E-08	6.30E-07	1.91E-09	1.12E-09	1.91E-10	1.96E-09	1.80E-07	1.91E-09	1.91E-09
RA-226	13	2.56E+00	1.19E+00	1.61E-01	2.04E-05	3.52E-02	3.07E-02	1.51E-03	1.09E-01	1.03E+00	1.52E-02	1.51E-02
RA-226	14	2.98E-02	1.39E-02	1.88E-03	2.38E-07	4.10E-04	3.58E-04	1.76E-05	1.27E-03	1.20E-02	1.77E-04	1.76E-04
RA-226	15	2.66E-03	1.24E-03	1.68E-04	2.13E-08	3.67E-05	3.20E-05	1.57E-06	1.14E-04	1.07E-03	1.58E-05	1.57E-05
RA-226	16	2.86E-03	1.68E-04	6.24E-04	5.52E-04	1.23E-04	2.25E-04	1.41E-05	1.17E-04	1.03E-03	1.09E-04	1.26E-04
RA-226	17	6.94E-02	4.76E-03	1.70E-03	4.86E-02	1.47E-04	8.65E-05	1.47E-05	1.51E-04	1.39E-02	1.47E-04	1.47E-04
RA-226	18	1.28E-05	7.72E-07	2.86E-06	2.62E-06	5.77E-07	1.06E-06	6.59E-08	5.46E-07	4.25E-06	5.10E-07	5.82E-07
RA-226	19	6.23E+01	2.90E+01	3.93E+00	4.98E-04	8.59E-01	7.50E-01	3.68E-02	2.66E+00	2.51E+01	3.70E-01	3.68E-01
RA-226	20	7.26E-01	3.38E-01	4.58E-02	5.80E-06	1.00E-02	8.74E-03	4.29E-04	3.10E-02	2.92E-01	4.31E-03	4.29E-03
RA-226	21	6.50E-02	3.03E-02	4.10E-03	5.19E-07	8.96E-04	7.82E-04	3.84E-05	2.77E-03	2.61E-02	3.86E-04	3.84E-04
RA-226	22	2.86E-03	1.68E-04	6.24E-04	5.52E-04	1.23E-04	2.25E-04	1.41E-05	1.17E-04	1.03E-03	1.09E-04	1.26E-04
RA-226	23	1.65E-10	1.00E-11	3.71E-11	3.39E-11	7.47E-12	1.37E-11	8.54E-13	7.07E-12	5.51E-11	6.60E-12	7.54E-12
RA-226	24	8.99E-07	6.16E-08	2.20E-08	6.30E-07	1.91E-09	1.12E-09	1.91E-10	1.96E-09	1.80E-07	1.91E-09	1.91E-09
RA-226	25	2.56E+00	1.19E+00	1.61E-01	2.04E-05	3.52E-02	3.07E-02	1.51E-03	1.09E-01	1.03E+00	1.52E-02	1.51E-02
RA-226	26	2.98E-02	1.39E-02	1.88E-03	2.38E-07	4.10E-04	3.58E-04	1.76E-05	1.27E-03	1.20E-02	1.77E-04	1.76E-04
RA-226	27	2.66E-03	1.24E-03	1.68E-04	2.13E-08	3.67E-05	3.20E-05	1.57E-06	1.14E-04	1.07E-03	1.58E-05	1.57E-05
RA-226	28	2.86E-03	1.68E-04	6.24E-04	5.52E-04	1.23E-04	2.25E-04	1.41E-05	1.17E-04	1.03E-03	1.09E-04	1.26E-04
RA-226	29	7.34E-03	3.42E-03	4.63E-04	5.87E-08	1.01E-04	8.83E-05	4.34E-06	3.13E-04	2.95E-03	4.36E-05	4.34E-05
RA-226	30	2.45E-03	1.14E-03	1.54E-04	1.96E-08	3.37E-05	2.94E-05	1.45E-06	1.04E-04	9.84E-04	1.45E-05	1.45E-05

NUCLIDE	PATHWAY	ORGAN ******FATAL CANCERS****** BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	FIRST GENERATION ***GENETIC EFFECTS*** OVARIES	TESTES
U-234	1	7.39E-02	4.02E-02	6.43E-03	6.62E-06	1.17E-03	3.56E-04	1.17E-04	1.71E-03	2.39E-02	1.17E-03	1.17E-03
U-234	2	1.23E-03	6.67E-04	1.07E-04	1.10E-07	1.93E-05	5.91E-06	1.93E-06	2.83E-05	3.97E-04	1.93E-05	1.93E-05
U-234	3	1.25E+00	6.80E-01	1.09E-01	1.12E-04	1.97E-02	6.02E-03	1.97E-03	2.89E-02	4.05E-01	1.97E-02	1.97E-02
U-234	4	6.14E-03	3.34E-03	5.34E-04	5.49E-07	9.68E-05	2.96E-05	9.68E-06	1.42E-04	1.99E-03	9.68E-05	9.68E-05
U-234	5	7.46E-06	4.06E-06	6.49E-07	6.68E-10	1.18E-07	3.60E-08	1.18E-08	1.72E-07	2.41E-06	1.18E-07	1.18E-07
U-234	6	6.26E-07	1.65E-07	2.69E-08	3.14E-07	4.76E-09	2.68E-10	4.76E-10	7.00E-09	1.08E-07	4.76E-09	4.76E-09
U-234	7	8.19E-07	6.25E-08	2.24E-07	8.75E-08	1.62E-08	3.64E-08	2.73E-09	1.73E-08	3.72E-07	1.41E-08	4.44E-08
U-234	8	4.27E-15	3.27E-16	1.17E-15	4.58E-16	8.48E-17	1.90E-16	1.42E-17	9.03E-17	1.94E-15	7.37E-17	2.32E-16
U-234	9	8.17E-06	4.44E-06	7.11E-07	7.32E-10	1.29E-07	3.94E-08	1.29E-08	1.89E-07	2.64E-06	1.29E-07	1.29E-07
U-234	10	1.36E-06	7.41E-07	1.19E-07	1.22E-10	2.15E-08	6.56E-09	2.15E-09	3.15E-08	4.41E-07	2.15E-08	2.15E-08
U-234	11	2.57E-14	1.96E-15	7.04E-15	2.75E-15	5.10E-16	1.14E-15	8.54E-17	5.42E-16	1.16E-14	4.43E-16	1.39E-15
U-234	12	6.64E-06	1.12E-07	1.82E-08	6.12E-06	3.31E-09	6.14E-10	3.31E-10	4.88E-09	3.84E-07	3.31E-09	3.31E-09
U-234	13	1.15E+00	6.26E-01	1.00E-01	1.03E-04	1.81E-02	5.54E-03	1.81E-03	2.66E-02	3.72E-01	1.81E-02	1.81E-02
U-234	14	5.40E-03	2.94E-03	4.70E-04	4.83E-07	8.52E-05	2.60E-05	8.52E-06	1.25E-04	1.75E-03	8.52E-05	8.52E-05
U-234	15	6.57E-06	3.57E-06	5.71E-07	5.88E-10	1.04E-07	3.16E-08	1.04E-08	1.52E-07	2.12E-06	1.04E-07	1.04E-07
U-234	16	4.92E-06	3.76E-07	1.35E-06	5.26E-07	9.74E-08	2.19E-07	1.64E-08	1.04E-07	2.23E-06	8.47E-08	2.67E-07
U-234	17	5.13E-01	8.65E-03	1.40E-03	4.72E-01	2.55E-04	4.74E-05	2.55E-05	3.76E-04	2.97E-02	2.55E-04	2.55E-04
U-234	18	1.98E-09	1.51E-10	5.44E-10	2.12E-10	3.93E-11	8.82E-11	6.59E-12	4.19E-11	8.98E-10	3.42E-11	1.08E-10
U-234	19	2.81E+01	1.53E+01	2.44E+00	2.51E-03	4.43E-01	1.35E-01	4.43E-02	6.49E-01	9.08E+00	4.43E-01	4.43E-01
U-234	20	1.32E-01	7.16E-02	1.15E-02	1.18E-05	2.08E-03	6.35E-04	2.08E-04	3.05E-03	4.26E-02	2.08E-03	2.08E-03
U-234	21	1.60E-04	8.71E-05	1.39E-05	1.43E-08	2.53E-06	7.72E-07	2.53E-07	3.70E-06	5.18E-05	2.53E-06	2.53E-06
U-234	22	4.92E-06	3.76E-07	1.35E-06	5.26E-07	9.74E-08	2.19E-07	1.64E-08	1.04E-07	2.23E-06	8.47E-08	2.67E-07
U-234	23	2.57E-14	1.96E-15	7.04E-15	2.75E-15	5.10E-16	1.14E-15	8.54E-17	5.42E-16	1.16E-14	4.43E-16	1.39E-15
U-234	24	6.64E-06	1.12E-07	1.82E-08	6.12E-06	3.31E-09	6.14E-10	3.31E-10	4.88E-09	3.84E-07	3.31E-09	3.31E-09
U-234	25	1.15E+00	6.26E-01	1.00E-01	1.03E-04	1.81E-02	5.54E-03	1.81E-03	2.66E-02	3.72E-01	1.81E-02	1.81E-02
U-234	26	5.40E-03	2.94E-03	4.70E-04	4.83E-07	8.52E-05	2.60E-05	8.52E-06	1.25E-04	1.75E-03	8.52E-05	8.52E-05
U-234	27	6.57E-06	3.57E-06	5.71E-07	5.88E-10	1.04E-07	3.16E-08	1.04E-08	1.52E-07	2.12E-06	1.04E-07	1.04E-07
U-234	28	4.92E-06	3.76E-07	1.35E-06	5.26E-07	9.74E-08	2.19E-07	1.64E-08	1.04E-07	2.23E-06	8.47E-08	2.67E-07
U-234	29	3.98E-04	2.17E-04	3.46E-05	3.56E-08	6.28E-06	1.92E-06	6.28E-07	9.20E-06	1.29E-04	6.28E-06	6.28E-06
U-234	30	6.63E-05	3.61E-05	5.77E-06	5.94E-09	1.05E-06	3.20E-07	1.05E-07	1.53E-06	2.15E-05	1.05E-06	1.05E-06

		ORGAN									
NUCLIDE	PATHWAY	********FATAL CANCERS********								FIRST GENERATION ***GENETIC EFFECTS***	
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
NP-237	1	1.30E-01	3.82E-02	4.98E-02	7.13E-06	1.65E-02	5.87E-04	1.22E-05	2.21E-03	2.25E-02	7.84E-05	2.41E-04
NP-237	2	2.15E-03	6.33E-04	8.27E-04	1.18E-07	2.73E-04	9.73E-06	2.03E-07	3.67E-05	3.73E-04	1.30E-06	4.00E-06
NP-237	3	4.60E-01	1.35E-01	1.77E-01	2.53E-05	5.84E-02	2.08E-03	4.33E-05	7.84E-03	7.98E-02	2.78E-04	8.55E-04
NP-237	4	9.21E-05	2.71E-05	3.53E-05	5.06E-09	1.17E-05	4.16E-07	8.66E-09	1.57E-06	1.60E-05	5.56E-08	1.71E-07
NP-237	5	3.90E-04	1.15E-04	1.50E-04	2.14E-08	4.95E-05	1.76E-06	3.67E-08	6.64E-06	6.76E-05	2.35E-07	7.25E-07
NP-237	6	2.18E-05	6.28E-06	8.37E-06	3.36E-07	2.78E-06	7.06E-10	2.07E-09	3.59E-07	3.73E-06	1.29E-08	3.92E-08
NP-237	7	1.05E-04	8.05E-06	2.99E-05	1.76E-05	3.84E-06	5.55E-06	4.96E-07	3.71E-06	3.55E-05	2.52E-06	5.94E-06
NP-237	8	4.71E-12	3.63E-13	1.35E-12	7.95E-13	1.73E-13	2.51E-13	2.39E-14	1.67E-13	1.59E-12	1.13E-13	2.68E-13
NP-237	9	1.44E-05	4.22E-06	5.51E-06	7.88E-10	1.82E-06	6.49E-08	1.35E-09	2.44E-07	2.49E-06	8.67E-09	2.67E-08
NP-237	10	2.39E-06	7.04E-07	9.19E-07	1.31E-10	3.04E-07	1.08E-08	2.25E-10	4.07E-08	4.15E-07	1.44E-09	4.44E-09
NP-237	11	2.83E-11	2.18E-12	8.08E-12	4.78E-12	1.04E-12	1.51E-12	1.43E-13	1.00E-12	9.57E-12	6.80E-13	1.61E-12
NP-237	12	2.42E-05	5.07E-06	6.75E-06	6.50E-06	2.25E-06	1.55E-09	1.68E-09	2.91E-07	3.33E-06	1.01E-08	3.25E-08
NP-237	13	4.23E-01	1.25E-01	1.63E-01	2.33E-05	5.38E-02	1.91E-03	3.99E-05	7.21E-03	7.34E-02	2.56E-04	7.87E-04
NP-237	14	8.10E-05	2.38E-05	3.11E-05	4.45E-09	1.03E-05	3.66E-07	7.62E-09	1.38E-06	1.40E-05	4.89E-08	1.50E-07
NP-237	15	3.43E-04	1.01E-04	1.32E-04	1.89E-08	4.36E-05	1.55E-06	3.23E-08	5.84E-06	5.95E-05	2.07E-07	6.38E-07
NP-237	16	6.29E-04	4.84E-05	1.79E-04	1.06E-04	2.31E-05	3.33E-05	2.98E-06	2.23E-05	2.13E-04	1.51E-05	3.57E-05
NP-237	17	1.87E+00	3.91E-01	5.21E-01	5.02E-01	1.74E-01	1.19E-04	1.30E-04	2.25E-02	2.57E-01	7.79E-04	2.51E-03
NP-237	18	2.19E-06	1.68E-07	6.24E-07	3.69E-07	8.03E-08	1.16E-07	1.11E-08	7.72E-08	7.39E-07	5.25E-08	1.24E-07
NP-237	19	1.03E+01	3.04E+00	3.97E+00	5.67E-04	1.31E+00	4.67E-02	9.72E-04	1.76E-01	1.79E+00	6.24E-03	1.92E-02
NP-237	20	1.98E-03	5.81E-04	7.59E-04	1.09E-07	2.51E-04	8.93E-06	1.86E-07	3.37E-05	3.43E-04	1.19E-06	3.67E-06
NP-237	21	8.37E-03	2.46E-03	3.21E-03	4.60E-07	1.06E-03	3.78E-05	7.88E-07	1.43E-04	1.45E-03	5.05E-06	1.56E-05
NP-237	22	6.29E-04	4.84E-05	1.79E-04	1.06E-04	2.31E-05	3.33E-05	2.98E-06	2.23E-05	2.13E-04	1.51E-05	3.57E-05
NP-237	23	2.83E-11	2.18E-12	8.08E-12	4.78E-12	1.04E-12	1.51E-12	1.43E-13	1.00E-12	9.57E-12	6.80E-13	1.61E-12
NP-237	24	2.42E-05	5.07E-06	6.75E-06	6.50E-06	2.25E-06	1.55E-09	1.68E-09	2.91E-07	3.33E-06	1.01E-08	3.25E-08
NP-237	25	4.23E-01	1.25E-01	1.63E-01	2.33E-05	5.38E-02	1.91E-03	3.99E-05	7.21E-03	7.34E-02	2.56E-04	7.87E-04
NP-237	26	8.10E-05	2.38E-05	3.11E-05	4.45E-09	1.03E-05	3.66E-07	7.62E-09	1.38E-06	1.40E-05	4.89E-08	1.50E-07
NP-237	27	3.43E-04	1.01E-04	1.32E-04	1.89E-08	4.36E-05	1.55E-06	3.23E-08	5.84E-06	5.95E-05	2.07E-07	6.38E-07
NP-237	28	6.29E-04	4.84E-05	1.79E-04	1.06E-04	2.31E-05	3.33E-05	2.98E-06	2.23E-05	2.13E-04	1.51E-05	3.57E-05
NP-237	29	6.99E-04	2.06E-04	2.68E-04	3.84E-08	8.88E-05	3.16E-06	6.58E-08	1.19E-05	1.21E-04	4.22E-07	1.30E-06
NP-237	30	1.17E-04	3.43E-05	4.47E-05	6.40E-09	1.48E-05	5.27E-07	1.10E-08	1.98E-06	2.02E-05	7.04E-08	2.17E-07

		ORGAN									
		******************************FATAL CANCERS**								FIRST GENERATION ***GENETIC EFFECTS***	
NUCLIDE	PATHWAY	BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
PU-238	1	3.92E-03	1.00E-03	1.37E-03	6.34E-10	4.42E-04	4.42E-04	3.30E-07	5.85E-05	6.08E-04	2.07E-06	6.43E-06
PU-238	2	2.28E-03	5.83E-04	7.93E-04	3.68E-10	2.57E-04	2.57E-04	1.91E-07	3.39E-05	3.53E-04	1.20E-06	3.73E-06
PU-238	3	1.42E-02	3.64E-03	4.95E-03	2.30E-09	1.60E-03	1.60E-03	1.19E-06	2.12E-04	2.20E-03	7.49E-06	2.33E-05
PU-238	4	3.03E-08	7.77E-09	1.06E-08	4.91E-15	3.42E-09	3.42E-09	2.55E-12	4.52E-10	4.70E-09	1.60E-11	4.97E-11
PU-238	5	1.16E-09	2.97E-10	4.03E-10	1.87E-16	1.31E-10	1.31E-10	9.73E-14	1.73E-11	1.79E-10	6.11E-13	1.90E-12
PU-238	6	1.99E-05	5.69E-06	7.59E-06	3.59E-07	2.54E-06	3.09E-10	1.85E-09	3.28E-07	3.39E-06	1.15E-08	3.64E-08
PU-238	7	4.28E-07	2.74E-08	9.51E-08	2.63E-08	2.89E-09	1.93E-08	5.34E-10	3.84E-09	2.53E-07	4.04E-09	2.87E-08
PU-238	8	2.18E-15	1.40E-16	4.84E-16	1.34E-16	1.48E-17	9.88E-17	2.73E-18	1.97E-17	1.29E-15	2.07E-17	1.47E-16
PU-238	9	1.52E-07	3.89E-08	5.29E-08	2.45E-14	1.71E-08	1.71E-08	1.28E-11	2.26E-09	2.35E-08	8.01E-11	2.49E-10
PU-238	10	7.23E-07	1.85E-07	2.52E-07	1.17E-13	8.15E-08	8.15E-08	6.07E-11	1.08E-08	1.12E-07	3.81E-10	1.19E-09
PU-238	11	1.31E-14	8.40E-16	2.91E-15	8.06E-16	8.87E-17	5.94E-16	1.64E-17	1.18E-16	7.75E-15	1.24E-16	8.80E-16
PU-238	12	2.25E-05	4.43E-06	5.92E-06	6.93E-06	1.99E-06	6.95E-10	1.46E-09	2.58E-07	2.98E-06	8.97E-09	2.80E-08
PU-238	13	1.31E-02	3.35E-03	4.55E-03	2.11E-09	1.47E-03	1.47E-03	1.10E-06	1.95E-04	2.02E-03	6.89E-06	2.14E-05
PU-238	14	2.67E-08	6.84E-09	9.30E-09	4.32E-15	3.01E-09	3.01E-09	2.24E-12	3.98E-10	4.14E-09	1.41E-11	4.38E-11
PU-238	15	1.02E-09	2.61E-10	3.55E-10	1.65E-16	1.15E-10	1.15E-10	8.56E-14	1.52E-11	1.58E-10	5.38E-13	1.67E-12
PU-238	16	2.57E-06	1.65E-07	5.71E-07	1.58E-07	1.73E-08	1.16E-07	3.21E-09	2.31E-08	1.52E-06	2.43E-08	1.72E-07
PU-238	17	1.74E+00	3.42E-01	4.57E-01	5.35E-01	1.54E-01	5.36E-05	1.12E-04	1.99E-02	2.30E-01	6.92E-04	2.16E-03
PU-238	18	1.01E-09	6.49E-11	2.25E-10	6.22E-11	6.85E-12	4.58E-11	1.27E-12	9.11E-12	5.98E-10	9.58E-12	6.80E-11
PU-238	19	3.19E-01	8.16E-02	1.11E-01	5.15E-08	3.59E-02	3.59E-02	2.68E-05	4.75E-03	4.94E-02	1.68E-04	5.22E-04
PU-238	20	6.51E-07	1.67E-07	2.27E-07	1.05E-13	7.34E-08	7.34E-08	5.47E-11	9.71E-09	1.01E-07	3.44E-10	1.07E-09
PU-238	21	2.49E-08	6.37E-09	8.66E-09	4.02E-15	2.80E-09	2.80E-09	2.09E-12	3.71E-10	3.85E-09	1.31E-11	4.08E-11
PU-238	22	2.57E-06	1.65E-07	5.71E-07	1.58E-07	1.73E-08	1.16E-07	3.21E-09	2.31E-08	1.52E-06	2.43E-08	1.72E-07
PU-238	23	1.31E-14	8.40E-16	2.91E-15	8.06E-16	8.87E-17	5.94E-16	1.64E-17	1.18E-16	7.75E-15	1.24E-16	8.80E-16
PU-238	24	2.25E-05	4.43E-06	5.92E-06	6.93E-06	1.99E-06	6.95E-10	1.46E-09	2.58E-07	2.98E-06	8.97E-09	2.80E-08
PU-238	25	1.31E-02	3.35E-03	4.55E-03	2.11E-09	1.47E-03	1.47E-03	1.10E-06	1.95E-04	2.02E-03	6.89E-06	2.14E-05
PU-238	26	2.67E-08	6.84E-09	9.30E-09	4.32E-15	3.01E-09	3.01E-09	2.24E-12	3.98E-10	4.14E-09	1.41E-11	4.38E-11
PU-238	27	1.02E-09	2.61E-10	3.55E-10	1.65E-16	1.15E-10	1.15E-10	8.56E-14	1.52E-11	1.58E-10	5.38E-13	1.67E-12
PU-238	28	2.57E-06	1.65E-07	5.71E-07	1.58E-07	1.73E-08	1.16E-07	3.21E-09	2.31E-08	1.52E-06	2.43E-08	1.72E-07
PU-238	29	7.39E-06	1.89E-06	2.58E-06	1.20E-12	8.34E-07	8.34E-07	6.21E-10	1.10E-07	1.15E-06	3.90E-09	1.21E-08
PU-238	30	3.52E-05	9.02E-06	1.23E-05	5.69E-12	3.97E-06	3.97E-06	2.96E-09	5.25E-07	5.46E-06	1.86E-08	5.77E-08

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                                                                           ORGAN                                                     FIRST GENERATION
NUCLIDE  PATHWAY*******************************FATAL CANCERS******************************************     ***GENETIC EFFECTS***
                   BONE    RED MARROW    LUNGS      LIVER       GI-LLI     THYROID    KIDNEYS  OTHERORGAN     OVARIES     TESTES
                                                                 WALL

 PU-239      1  4.32E-03  1.15E-03  1.53E-03  4.90E-10  5.02E-04  3.96E-04  3.72E-07  6.47E-05  6.78E-04     2.31E-06  7.24E-06
 PU-239      2  2.50E-03  6.65E-04  8.87E-04  2.84E-10  2.92E-04  2.30E-04  2.16E-07  3.76E-05  3.94E-04     1.34E-06  4.20E-06
 PU-239      3  2.51E-02  6.67E-03  8.89E-03  2.85E-09  2.92E-03  2.31E-03  2.16E-06  3.77E-04  3.95E-03     1.35E-05  4.21E-05
 PU-239      4  5.39E-08  1.43E-08  1.91E-08  6.12E-15  6.28E-09  4.95E-09  4.65E-12  8.09E-10  8.48E-09     2.89E-11  9.05E-11
 PU-239      5  2.06E-09  5.46E-10  7.28E-10  2.33E-16  2.40E-10  1.89E-10  1.77E-13  3.09E-11  3.23E-10     1.10E-12  3.45E-12
 PU-239      6  2.22E-05  6.39E-06  8.53E-06  3.36E-07  2.80E-06  2.87E-10  2.07E-09  3.64E-07  3.77E-06     1.29E-08  4.20E-08
 PU-239      7  1.95E-07  1.35E-08  4.75E-08  1.44E-08  1.98E-09  8.00E-09  3.99E-10  2.59E-09  1.07E-07     2.45E-09  1.29E-08
 PU-239      8  1.03E-15  7.12E-17  2.49E-16  7.60E-17  1.04E-17  4.22E-17  2.10E-18  1.37E-17  5.61E-16     1.30E-17  6.79E-17
 PU-239      9  1.67E-07  4.43E-08  5.91E-08  1.89E-14  1.94E-08  1.53E-08  1.44E-11  2.50E-09  2.62E-08     8.94E-11  2.80E-10
 PU-239     10  7.95E-07  2.11E-07  2.81E-07  9.02E-14  9.26E-08  7.30E-08  6.85E-11  1.19E-08  1.25E-07     4.26E-10  1.33E-09
 PU-239     11  6.16E-15  4.28E-16  1.50E-15  4.56E-16  6.26E-17  2.53E-16  1.26E-17  8.20E-17  3.37E-15     7.80E-17  4.08E-16
 PU-239     12  2.44E-05  5.11E-06  6.81E-06  6.59E-06  2.26E-06  6.48E-10  1.68E-09  2.91E-07  3.37E-06     1.01E-08  3.25E-08
 PU-239     13  2.31E-02  6.14E-03  8.18E-03  2.62E-09  2.69E-03  2.12E-03  1.99E-06  3.47E-04  3.63E-03     1.24E-05  3.88E-05
 PU-239     14  4.75E-08  1.26E-08  1.68E-08  5.39E-15  5.53E-09  4.36E-09  4.09E-12  7.12E-10  7.46E-09     2.54E-11  7.96E-11
 PU-239     15  1.81E-09  4.81E-10  6.41E-10  2.05E-16  2.11E-10  1.66E-10  1.56E-13  2.71E-11  2.84E-10     9.70E-13  3.04E-12
 PU-239     16  1.17E-06  8.14E-08  2.85E-07  8.64E-08  1.19E-08  4.80E-08  2.39E-09  1.55E-08  6.40E-07     1.47E-08  7.74E-08
 PU-239     17  1.89E+00  3.95E-01  5.26E-01  5.09E-01  1.75E-01  5.00E-05  1.30E-04  2.25E-02  2.60E-01     7.79E-04  2.51E-03
 PU-239     18  4.76E-10  3.30E-11  1.16E-10  3.52E-11  4.83E-12  1.96E-11  9.73E-13  6.33E-12  2.60E-10     6.02E-12  3.15E-11
 PU-239     19  5.64E-01  1.50E-01  2.00E-01  6.40E-08  6.56E-02  5.18E-02  4.86E-05  8.46E-03  8.86E-02     3.02E-04  9.45E-04
 PU-239     20  1.16E-06  3.07E-07  4.10E-07  1.31E-13  1.35E-07  1.06E-07  9.98E-11  1.74E-08  1.82E-07     6.20E-10  1.94E-09
 PU-239     21  4.42E-08  1.17E-08  1.56E-08  5.01E-15  5.14E-09  4.06E-09  3.81E-12  6.62E-10  6.94E-09     2.37E-11  7.40E-11
 PU-239     22  1.17E-06  8.14E-08  2.85E-07  8.64E-08  1.19E-08  4.80E-08  2.39E-09  1.55E-08  6.40E-07     1.47E-08  7.74E-08
 PU-239     23  6.16E-15  4.28E-16  1.50E-15  4.56E-16  6.26E-17  2.53E-16  1.26E-17  8.20E-17  3.37E-15     7.80E-17  4.08E-16
 PU-239     24  2.44E-05  5.11E-06  6.81E-06  6.59E-06  2.26E-06  6.48E-10  1.68E-09  2.91E-07  3.37E-06     1.01E-08  3.25E-08
 PU-239     25  2.31E-02  6.14E-03  8.18E-03  2.62E-09  2.69E-03  2.12E-03  1.99E-06  3.47E-04  3.63E-03     1.24E-05  3.88E-05
 PU-239     26  4.75E-08  1.26E-08  1.68E-08  5.39E-15  5.53E-09  4.36E-09  4.09E-12  7.12E-10  7.46E-09     2.54E-11  7.96E-11
 PU-239     27  1.81E-09  4.81E-10  6.41E-10  2.05E-16  2.11E-10  1.66E-10  1.56E-13  2.71E-11  2.84E-10     9.70E-13  3.04E-12
 PU-239     28  1.17E-06  8.14E-08  2.85E-07  8.64E-08  1.19E-08  4.80E-08  2.39E-09  1.55E-08  6.40E-07     1.47E-08  7.74E-08
 PU-239     29  8.13E-06  2.16E-06  2.88E-06  9.23E-13  9.47E-07  7.47E-07  7.01E-10  1.22E-07  1.28E-06     4.36E-09  1.36E-08
 PU-239     30  3.87E-05  1.03E-05  1.37E-05  4.40E-12  4.51E-06  3.56E-06  3.34E-09  5.81E-07  6.09E-06     2.07E-08  6.50E-08
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					ORGAN						
NUCLIDE	PATHWAY	***FATAL CANCERS***								FIRST GENERATION ***GENETIC EFFECTS***	
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
PU-240	1	4.32E-03	1.15E-03	1.53E-03	6.69E-10	5.02E-04	3.99E-04	3.70E-07	6.47E-05	6.80E-04	2.31E-06	7.24E-06
PU-240	2	2.51E-03	6.65E-04	8.87E-04	3.88E-10	2.92E-04	2.32E-04	2.15E-07	3.76E-05	3.94E-04	1.34E-06	4.20E-06
PU-240	3	2.37E-02	6.30E-03	8.40E-03	3.68E-09	2.76E-03	2.19E-03	2.03E-06	3.56E-04	3.74E-03	1.27E-05	3.98E-05
PU-240	4	5.16E-08	1.37E-08	1.82E-08	7.99E-15	6.00E-09	4.77E-09	4.42E-12	7.73E-10	8.11E-09	2.76E-11	8.64E-11
PU-240	5	1.97E-09	5.22E-10	6.96E-10	3.05E-16	2.29E-10	1.82E-10	1.69E-13	2.95E-11	3.10E-10	1.05E-12	3.30E-12
PU-240	6	2.23E-05	6.39E-06	8.52E-06	3.47E-07	2.83E-06	2.90E-10	2.07E-09	3.64E-07	3.80E-06	1.29E-08	4.20E-08
PU-240	7	3.83E-07	2.50E-08	8.71E-08	2.51E-08	3.02E-09	1.73E-08	5.48E-10	3.85E-09	2.22E-07	3.91E-09	2.53E-08
PU-240	8	1.96E-15	1.29E-16	4.44E-16	1.28E-16	1.55E-17	8.86E-17	2.81E-1[illegible]	1.98E-17	1.13E-15	2.00E-17	1.30E-16
PU-240	9	1.67E-07	4.43E-08	5.91E-08	2.59E-14	1.94E-08	1.54E-08	1.43E-11	2.50E-09	2.63E-08	8.94E-11	2.80E-10
PU-240	10	7.96E-07	2.11E-07	2.81E-07	1.23E-13	9.26E-08	7.36E-08	6.81E-11	1.19E-08	1.25E-07	4.26E-10	1.33E-09
PU-240	11	1.18E-14	7.74E-16	2.67E-15	7.71E-16	9.34E-17	5.32E-16	1.69E-17	1.19E-16	6.82E-15	1.20E-16	7.80E-16
PU-240	12	2.45E-05	5.12E-06	6.81E-06	6.61E-06	2.27E-06	6.52E-10	1.68E-09	2.91E-07	3.37E-06	1.01E-08	3.25E-08
PU-240	13	2.18E-02	5.79E-03	7.73E-03	3.38E-09	2.54E-03	2.02E-03	1.87E-06	3.27E-04	3.44E-03	1.17E-05	3.66E-05
PU-240	14	4.54E-08	1.20E-08	1.61E-08	7.03E-15	5.28E-09	4.19E-09	3.89E-12	6.80E-10	7.14E-09	2.43E-11	7.60E-11
PU-240	15	1.73E-09	4.60E-10	6.13E-10	2.68E-16	2.02E-10	1.60E-10	1.48E-13	2.60E-11	2.73E-10	9.27E-13	2.90E-12
PU-240	16	2.30E-06	1.50E-07	5.23E-07	1.50E-07	1.81E-08	1.04E-07	3.29E-09	2.31E-08	1.33E-06	2.35E-08	1.52E-07
PU-240	17	1.89E+00	3.95E-01	5.26E-01	5.10E-01	1.75E-01	5.04E-05	1.30E-04	2.25E-02	2.60E-01	7.79E-04	2.51E-03
PU-240	18	9.10E-10	5.97E-11	2.06E-10	5.95E-11	7.21E-12	4.11E-11	1.30E-12	9.17E-12	5.26E-10	9.27E-12	6.02E-11
PU-240	19	5.33E-01	1.41E-01	1.88E-01	8.25E-08	6.20E-02	4.93E-02	4.56E-05	7.99E-03	8.38E-02	2.85E-04	8.93E-04
PU-240	20	1.11E-06	2.94E-07	3.92E-07	1.71E-13	1.29E-07	1.02E-07	9.48E-11	1.66E-08	1.74E-07	5.93E-10	1.85E-09
PU-240	21	4.23E-08	1.12E-08	1.49E-08	6.55E-15	4.92E-09	3.91E-09	3.62E-12	6.33E-10	6.65E-09	2.26E-11	7.08E-11
PU-240	22	2.30E-06	1.50E-07	5.23E-07	1.50E-07	1.81E-08	1.04E-07	3.29E-09	2.31E-08	1.33E-06	2.35E-08	1.52E-07
PU-240	23	1.18E-14	7.74E-16	2.67E-15	7.71E-16	9.34E-17	5.32E-16	1.69E-17	1.19E-16	6.82E-15	1.20E-16	7.80E-16
PU-240	24	2.45E-05	5.12E-06	6.81E-06	6.61E-06	2.27E-06	6.52E-10	1.68E-09	2.91E-07	3.37E-06	1.01E-08	3.25E-08
PU-240	25	2.18E-02	5.79E-03	7.73E-03	3.38E-09	2.54E-03	2.02E-03	1.87E-06	3.27E-04	3.44E-03	1.17E-05	3.66E-05
PU-240	26	4.54E-08	1.20E-08	1.61E-08	7.03E-15	5.28E-09	4.19E-09	3.89E-12	6.80E-10	7.14E-09	2.43E-11	7.60E-11
PU-240	27	1.73E-09	4.60E-10	6.13E-10	2.68E-16	2.02E-10	1.60E-10	1.48E-13	2.60E-11	2.73E-10	9.27E-13	2.90E-12
PU-240	28	2.30E-06	1.50E-07	5.23E-07	1.50E-07	1.81E-08	1.04E-07	3.29E-09	2.31E-08	1.33E-06	2.35E-08	1.52E-07
PU-240	29	8.14E-06	2.16E-06	2.88E-06	1.26E-12	9.47E-07	7.52E-07	6.97E-10	1.22E-07	1.28E-06	4.36E-09	1.36E-08
PU-240	30	3.88E-05	1.03E-05	1.37E-05	6.00E-12	4.51E-06	3.58E-06	3.32E-09	5.81E-07	6.10E-06	2.07E-08	6.50E-08

NUCLIDE	PATHWAY	ORGAN **********FATAL CANCERS********** BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL		THYROID	KIDNEYS	OTHERORGAN	FIRST GENERATION ***GENETIC EFFECTS*** OVARIES	TESTES
AM-241	1	1.32E-01	3.82E-02	5.15E-02	1.02E-06	1.71E-02	4.42E-04	1.27E-05	2.21E-03	2.25E-02	7.92E-05	2.41E-04
AM-241	2	5.47E-03	1.58E-03	2.13E-03	4.23E-08	7.08E-04	1.83E-05	5.27E-07	9.17E-05	9.33E-04	3.28E-06	1.00E-05
AM-241	3	5.61E-01	1.62E-01	2.19E-01	4.34E-06	7.27E-02	1.88E-03	5.40E-05	9.40E-03	9.58E-02	3.37E-04	1.03E-03
AM-241	4	8.32E-04	2.41E-04	3.24E-04	6.44E-09	1.08E-04	2.79E-06	8.01E-08	1.39E-05	1.42E-04	4.99E-07	1.52E-06
AM-241	5	3.91E-06	1.13E-06	1.53E-06	3.03E-11	5.06E-07	1.31E-08	3.77E-10	6.55E-08	6.67E-07	2.35E-09	7.15E-09
AM-241	6	2.29E-05	6.58E-06	8.78E-06	3.59E-07	2.91E-06	3.42E-10	2.16E-09	3.75E-07	3.90E-06	1.34E-08	4.20E-08
AM-241	7	1.73E-05	1.58E-06	5.77E-06	2.35E-06	4.81E-07	6.57E-07	8.01E-08	5.10E-07	5.83E-06	4.93E-07	7.30E-07
AM-241	8	3.30E-13	3.02E-14	1.10E-13	4.49E-14	9.22E-15	1.26E-14	1.53E-15	9.77E-15	1.12E-13	9.45E-15	1.40E-14
AM-241	9	3.65E-05	1.06E-05	1.42E-05	2.82E-10	4.72E-06	1.22E-07	3.51E-09	6.11E-07	6.22E-06	2.19E-08	6.67E-08
AM-241	10	2.43E-04	7.04E-05	9.48E-05	1.88E-09	3.15E-05	8.15E-07	2.34E-08	4.07E-06	4.15E-05	1.46E-07	4.44E-07
AM-241	11	1.98E-12	1.81E-13	6.62E-13	2.69E-13	5.54E-14	7.58E-14	9.20E-15	5.87E-14	6.72E-13	5.68E-14	8.40E-14
AM-241	12	2.55E-05	5.28E-06	7.04E-06	7.02E-06	2.35E-06	7.31E-10	1.74E-09	3.03E-07	3.49E-06	1.06E-08	3.36E-08
AM-241	13	5.16E-01	1.49E-01	2.01E-01	4.00E-06	6.69E-02	1.73E-03	4.97E-05	8.65E-03	8.81E-02	3.10E-04	9.44E-04
AM-241	14	7.32E-04	2.12E-04	2.86E-04	5.67E-09	9.48E-05	2.45E-06	7.05E-08	1.23E-05	1.25E-04	4.39E-07	1.34E-06
AM-241	15	3.44E-06	9.96E-07	1.34E-06	2.66E-11	4.46E-07	1.15E-08	3.31E-10	5.77E-08	5.87E-07	2.07E-09	6.29E-09
AM-241	16	1.04E-04	9.47E-06	3.47E-05	1.41E-05	2.89E-06	3.95E-06	4.81E-07	3.06E-06	3.50E-05	2.96E-06	4.38E-06
AM-241	17	1.97E+00	4.08E-01	5.43E-01	5.42E-01	1.81E-01	5.64E-05	1.34E-04	2.34E-02	2.70E-01	8.22E-04	2.60E-03
AM-241	18	1.53E-07	1.40E-08	5.11E-08	2.08E-08	4.27E-09	5.85E-09	7.11E-10	4.53E-09	5.19E-08	4.38E-09	6.49E-09
AM-241	19	1.26E+01	3.65E+00	4.91E+00	9.75E-05	1.63E+00	4.22E-02	1.21E-03	2.11E-01	2.15E+00	7.56E-03	2.30E-02
AM-241	20	1.79E-02	5.17E-03	6.97E-03	1.38E-07	2.31E-03	5.99E-05	1.72E-06	2.99E-04	3.05E-03	1.07E-05	3.27E-05
AM-241	21	8.40E-05	2.43E-05	3.27E-05	6.50E-10	1.09E-05	2.81E-07	8.08E-09	1.41E-06	1.43E-05	5.04E-08	1.54E-07
AM-241	22	1.04E-04	9.47E-06	3.47E-05	1.41E-05	2.89E-06	3.95E-06	4.81E-07	3.06E-06	3.50E-05	2.96E-06	4.38E-06
AM-241	23	1.98E-12	1.81E-13	6.62E-13	2.69E-13	5.54E-14	7.58E-14	9.20E-15	5.87E-14	6.72E-13	5.68E-14	8.40E-14
AM-241	24	2.55E-05	5.28E-06	7.04E-06	7.02E-06	2.35E-06	7.31E-10	1.74E-09	3.03E-07	3.49E-06	1.06E-08	3.36E-08
AM-241	25	5.16E-01	1.49E-01	2.01E-01	4.00E-06	6.69E-02	1.73E-03	4.97E-05	8.65E-03	8.81E-02	3.10E-04	9.44E-04
AM-241	26	7.32E-04	2.12E-04	2.86E-04	5.67E-09	9.48E-05	2.45E-06	7.05E-08	1.23E-05	1.25E-04	4.39E-07	1.34E-06
AM-241	27	3.44E-06	9.96E-07	1.34E-06	2.66E-11	4.46E-07	1.15E-08	3.31E-10	5.77E-08	5.87E-07	2.07E-09	6.29E-09
AM-241	28	1.04E-04	9.47E-06	3.47E-05	1.41E-05	2.89E-06	3.95E-06	4.81E-07	3.06E-06	3.50E-05	2.96E-06	4.38E-06
AM-241	29	1.78E-03	5.14E-04	6.93E-04	1.37E-08	2.30E-04	5.95E-06	1.71E-07	2.98E-05	3.03E-04	1.07E-06	3.25E-06
AM-241	30	1.18E-02	3.43E-03	4.62E-03	9.17E-08	1.53E-03	3.97E-05	1.14E-06	1.98E-04	2.02E-03	7.11E-06	2.17E-05

NUCLIDE	PATHWAY	ORGAN ***FATAL CANCERS***								FIRST GENERATION ***GENETIC EFFECTS***	
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
PU-242	1	4.10E-03	1.09E-03	1.45E-03	1.29E-09	4.82E-04	3.78E-04	3.54E-07	6.15E-05	6.47E-04	2.19E-06	6.87E-06
PU-242	2	2.38E-03	6.30E-04	8.40E-04	7.47E-10	2.80E-04	2.19E-04	2.05E-07	3.57E-05	3.76E-04	1.27E-06	3.99E-06
PU-242	3	2.43E-02	6.44E-03	8.59E-03	7.63E-09	2.86E-03	2.24E-03	2.10E-06	3.65E-04	3.84E-03	1.30E-05	4.08E-05
PU-242	4	4.44E-08	1.17E-08	1.57E-08	1.39E-14	5.22E-09	4.09E-09	3.83E-12	6.66E-10	7.00E-09	2.37E-11	7.44E-11
PU-242	5	4.29E-08	1.13E-08	1.51E-08	1.34E-14	5.04E-09	3.95E-09	3.70E-12	6.43E-10	6.76E-09	2.29E-11	7.18E-11
PU-242	6	2.11E-05	6.08E-06	8.09E-06	3.25E-07	2.68E-06	2.75E-10	1.99E-09	3.45E-07	3.61E-06	1.23E-08	3.92E-08
PU-242	7	3.54E-07	2.25E-08	7.77E-08	2.06E-08	2.04E-09	1.59E-08	3.85E-10	2.88E-09	2.11E-07	3.30E-09	2.41E-08
PU-242	8	1.81E-15	1.15E-16	3.97E-16	1.05E-16	1.04E-17	8.11E-17	1.97E-18	1.47E-17	1.08E-15	1.68E-17	1.22E-16
PU-242	9	1.59E-07	4.20E-08	5.60E-08	4.98E-14	1.87E-08	1.46E-08	1.37E-11	2.38E-09	2.50E-08	8.48E-11	2.66E-10
PU-242	10	7.56E-07	2.00E-07	2.67E-07	2.37E-13	8.89E-08	6.96E-08	6.52E-11	1.13E-08	1.19E-07	4.04E-10	1.27E-09
PU-242	11	1.08E-14	6.94E-16	2.38E-15	6.30E-16	6.25E-17	4.87E-16	1.18E-17	8.80E-17	6.49E-15	1.01E-16	7.34E-16
PU-242	12	2.33E-05	4.87E-06	6.48E-06	6.28E-06	2.16E-06	6.18E-10	1.57E-09	2.80E-07	3.22E-06	1.01E-08	3.08E-08
PU-242	13	2.24E-02	5.92E-03	7.90E-03	7.02E-09	2.63E-03	2.06E-03	1.93E-06	3.36E-04	3.53E-03	1.20E-05	3.75E-05
PU-242	14	3.91E-08	1.03E-08	1.38E-08	1.22E-14	4.59E-09	3.60E-09	3.37E-12	5.86E-10	6.16E-09	2.09E-11	6.55E-11
PU-242	15	3.77E-08	9.98E-09	1.33E-08	1.18E-14	4.44E-09	3.47E-09	3.25E-12	5.65E-10	5.95E-09	2.01E-11	6.32E-11
PU-242	16	2.12E-06	1.35E-07	4.67E-07	1.24E-07	1.23E-08	9.55E-08	2.31E-09	1.73E-08	1.27E-06	1.98E-08	1.45E-07
PU-242	17	1.80E+00	3.76E-01	5.00E-01	4.84E-01	1.67E-01	4.77E-05	1.21E-04	2.16E-02	2.48E-01	7.79E-04	2.38E-03
PU-242	18	8.37E-10	5.36E-11	1.84E-10	4.86E-11	4.82E-12	3.76E-11	9.11E-13	6.80E-12	5.01E-10	7.78E-12	5.66E-11
PU-242	19	5.46E-01	1.45E-01	1.93E-01	1.71E-07	6.42E-02	5.03E-02	4.71E-05	8.19E-03	8.62E-02	2.92E-04	9.15E-04
PU-242	20	9.53E-07	2.52E-07	3.36E-07	2.99E-13	1.12E-07	8.78E-08	8.22E-11	1.43E-08	1.50E-07	5.09E-10	1.60E-09
PU-242	21	9.20E-07	2.43E-07	3.25E-07	2.89E-13	1.08E-07	8.48E-08	7.93E-11	1.38E-08	1.45E-07	4.91E-10	1.54E-09
PU-242	22	2.12E-06	1.35E-07	4.67E-07	1.24E-07	1.23E-08	9.55E-08	2.31E-09	1.73E-08	1.27E-06	1.98E-08	1.45E-07
PU-242	23	1.08E-14	6.94E-16	2.38E-15	6.30E-16	6.25E-17	4.87E-16	1.18E-17	8.80E-17	6.49E-15	1.01E-16	7.34E-16
PU-242	24	2.33E-05	4.87E-06	6.48E-06	6.28E-06	2.16E-06	6.18E-10	1.57E-09	2.80E-07	3.22E-06	1.01E-08	3.08E-08
PU-242	25	2.24E-02	5.92E-03	7.90E-03	7.02E-09	2.63E-03	2.06E-03	1.93E-06	3.36E-04	3.53E-03	1.20E-05	3.75E-05
PU-242	26	3.91E-08	1.03E-08	1.38E-08	1.22E-14	4.59E-09	3.60E-09	3.37E-12	5.86E-10	6.16E-09	2.09E-11	6.55E-11
PU-242	27	3.77E-08	9.98E-09	1.33E-08	1.18E-14	4.44E-09	3.47E-09	3.25E-12	5.65E-10	5.95E-09	2.01E-11	6.32E-11
PU-242	28	2.12E-06	1.35E-07	4.67E-07	1.24E-07	1.23E-08	9.55E-08	2.31E-09	1.73E-08	1.27E-06	1.98E-08	1.45E-07
PU-242	29	7.73E-06	2.05E-06	2.73E-06	2.42E-12	9.09E-07	7.12E-07	6.67E-10	1.16E-07	1.22E-06	4.13E-09	1.30E-08
PU-242	30	3.68E-05	9.74E-06	1.30E-05	1.15E-11	4.33E-06	3.39E-06	3.18E-09	5.52E-07	5.81E-06	1.97E-08	6.17E-08

ORGAN

NUCLIDE	PATHWAY	FATAL CANCERS								FIRST GENERATION ***GENETIC EFFECTS***	
		BONE	RED MARROW	LUNGS	LIVER	GI-LLI WALL	THYROID	KIDNEYS	OTHERORGAN	OVARIES	TESTES
AM-243	1	3.38E-01	3.82E-02	2.57E-01	7.75E-06	1.71E-02	5.99E-04	1.27E-05	2.21E-03	2.25E-02	8.18E-05	2.41E-04
AM-243	2	1.40E-02	1.58E-03	1.07E-02	3.21E-07	7.08E-04	2.48E-05	5.28E-07	9.17E-05	9.33E-04	3.39E-06	1.00E-05
AM-243	3	2.13E+00	2.40E-01	1.62E+00	4.88E-05	1.08E-01	3.77E-03	8.02E-05	1.39E-02	1.42E-01	5.15E-04	1.52E-03
AM-243	4	3.28E-03	3.70E-04	2.50E-03	7.52E-08	1.66E-04	5.81E-06	1.24E-07	2.14E-05	2.18E-04	7.94E-07	2.34E-06
AM-243	5	1.55E-05	1.76E-06	1.18E-05	3.56E-10	7.85E-07	2.75E-08	5.86E-10	1.02E-07	1.03E-06	3.76E-09	1.11E-08
AM-243	6	5.75E-05	6.56E-06	4.34E-05	3.47E-07	2.91E-06	8.41E-10	2.16E-09	3.75E-07	3.90E-06	1.34E-08	4.20E-08
AM-243	7	7.26E-05	5.87E-06	2.17E-05	1.17E-05	2.51E-06	3.58E-06	3.62E-07	2.45E-06	2.45E-05	1.83E-06	3.86E-06
AM-243	8	2.97E-12	2.41E-13	8.93E-13	4.71E-13	1.02E-13	1.44E-13	1.48E-14	9.96E-14	1.00E-12	7.51E-14	1.57E-13
AM-243	9	9.34E-05	1.06E-05	7.11E-05	2.14E-09	4.72E-06	1.66E-07	3.52E-09	6.11E-07	6.22E-06	2.26E-08	6.67E-08
AM-243	10	6.23E-04	7.04E-05	4.74E-04	1.43E-08	3.15E-05	1.10E-06	2.35E-08	4.07E-06	4.15E-05	1.51E-07	4.44E-07
AM-243	11	1.78E-11	1.45E-12	5.36E-12	2.83E-12	6.10E-13	8.66E-13	8.87E-14	5.98E-13	6.02E-12	4.51E-13	9.40E-13
AM-243	12	5.32E-05	5.28E-06	3.50E-05	6.79E-06	2.36E-06	3.61E-09	1.74E-09	3.03E-07	3.49E-06	1.06E-08	3.36E-08
AM-243	13	1.96E+00	2.21E-01	1.49E+00	4.49E-05	9.89E-02	3.47E-03	7.38E-05	1.28E-02	1.30E-01	4.74E-04	1.40E-03
AM-243	14	2.88E-03	3.26E-04	2.20E-03	6.62E-08	1.46E-04	5.11E-06	1.09E-07	1.89E-05	1.92E-04	6.98E-07	2.06E-06
AM-243	15	1.37E-05	1.54E-06	1.04E-05	3.14E-10	6.91E-07	2.42E-08	5.16E-10	8.94E-08	9.11E-07	3.31E-09	9.76E-09
AM-243	16	4.36E-04	3.53E-05	1.30E-04	7.02E-05	1.51E-05	2.15E-05	2.17E-06	1.47E-05	1.47E-04	1.10E-05	2.32E-05
AM-243	17	4.11E+00	4.08E-01	2.70E+00	5.24E-01	1.82E-01	2.79E-04	1.34E-04	2.34E-02	2.70E-01	8.22E-04	2.60E-03
AM-243	18	1.38E-06	1.12E-07	4.14E-07	2.18E-07	4.71E-08	6.68E-08	6.85E-09	4.62E-08	4.65E-07	3.48E-08	7.26E-08
AM-243	19	4.77E+01	5.39E+00	3.63E+01	1.09E-03	2.41E+00	8.46E-02	1.80E-03	3.12E-01	3.18E+00	1.16E-02	3.41E-02
AM-243	20	7.04E-02	7.95E-03	5.36E-02	1.61E-06	3.56E-03	1.25E-04	2.65E-06	4.60E-04	4.69E-03	1.70E-05	5.02E-05
AM-243	21	3.33E-04	3.77E-05	2.54E-04	7.65E-09	1.69E-05	5.91E-07	1.26E-08	2.18E-06	2.22E-05	8.07E-08	2.38E-07
AM-243	22	4.36E-04	3.53E-05	1.30E-04	7.02E-05	1.51E-05	2.15E-05	2.17E-06	1.47E-05	1.47E-04	1.10E-05	2.32E-05
AM-243	23	1.78E-11	1.45E-12	5.36E-12	2.83E-12	6.10E-13	8.66E-13	8.87E-14	5.98E-13	6.02E-12	4.51E-13	9.40E-13
AM-243	24	5.32E-05	5.28E-06	3.50E-05	6.79E-06	2.36E-06	3.61E-09	1.74E-09	3.03E-07	3.49E-06	1.06E-08	3.36E-08
AM-243	25	1.96E+00	2.21E-01	1.49E+00	4.49E-05	9.89E-02	3.47E-03	7.38E-05	1.28E-02	1.30E-01	4.74E-04	1.40E-03
AM-243	26	2.88E-03	3.26E-04	2.20E-03	6.62E-08	1.46E-04	5.11E-06	1.09E-07	1.89E-05	1.92E-04	6.98E-07	2.06E-06
AM-243	27	1.37E-05	1.54E-06	1.04E-05	3.14E-10	6.91E-07	2.42E-08	5.16E-10	8.94E-08	9.11E-07	3.31E-09	9.76E-09
AM-243	28	4.36E-04	3.53E-05	1.30E-04	7.02E-05	1.51E-05	2.15E-05	2.17E-06	1.47E-05	1.47E-04	1.10E-05	2.32E-05
AM-243	29	4.55E-03	5.14E-04	3.46E-03	1.04E-07	2.30E-04	8.06E-06	1.72E-07	2.98E-05	3.03E-04	1.10E-06	3.25E-06
AM-243	30	3.03E-02	3.43E-03	2.31E-02	6.96E-07	1.53E-03	5.38E-05	1.14E-06	1.98E-04	2.02E-03	7.34E-06	2.17E-05